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HACKENSACK MEADOWLANDS AIR POLLUTION STUDY. EVALUATION AND RANKING OF LAND USE PLANS

Byron H. Willis

Environmental Research and Technology,
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16. ABSTRACT

The Hackensack Meadowlands Air Pollution Study consists of a summary report and five task reports. The summary report discusses the procedures developed for considering air pollution in the planning process and the use of these procedures to evaluate four alternative land use plans for the New Jersey Hackensack Meadowlands for 1990. The task reports describe (1) the emission projection methodology and its application to the Hackensack Meadowlands; (2) the model for predicting air quality levels and its validation and calibration: (3) the evaluation and ranking of the land use plans; (4) the planning guidelines derived from the analysis of the plans; and (5) the software system.

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PREFACE

The Hackensack Meadowlands Air Pollution Study final report consists of a summary report, five task reports, and three appendices, each bound separately. This report is the third of the five task reports. Its purpose is to describe the procedures developed for incorporating air pollution considerations into the formulation, evaluation and ranking of alternative urban land use and transportation system plans and policies; and to describe the results of the evaluation and ranking of four alternative land use plans for 1990 for the New Jersey Hackensack Meadowlands.

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1. SUMMARY AND CONCLUSIONS

1.1 Task Objectives

This report documents the results of the Task 5 studies undertaken by Environmental Research & Technology, Inc. (ERT) as part of the Hackensack Meadowlands Air Pollution Study. The two principal objectives of this task were to develop procedures for incorporating air pollution considerations into the formulation and evaluation of alternative urban land use and transportation system plans and policies; and to demonstrate these procedures through application to the evaluation and ranking of the 1990 comprehensive land use plans for the New Jersey Hackensack Meadowlands Region. The specific work undertaken as part of this task included a survey of planning agencies to determine the extent to which air pollution considerations have been or will be included in the planning process, the development of methodologies to permit planners to assess the air pollution impact associated with land use plans, the development of methodologies to permit planners to rank and evaluate alternative land use plans in terms of air quality criteria, and the analysis of the regional air quality impact associated with the four alternative land use plans for the Hackensack Meadowlands for the 1990 time period.

1.2 Results of the Survey of Planning Agencies

A survey of both land use and transportation system planning agencies was conducted to determine the extent to which air pollution considerations are currently being considered in the development of plans, and to determine the basic requirements for procedures and methodologies which would facilitate the consideration of air pollution in the planning process.

The survey showed a wide variation in the extent of current considerations of air pollution by urban planners and in the attitudes toward the priority and role of air pollution as a consideration in the planning process. It was found in general that air pollution currently is not (and historically has not been) an issue of primary concern among planners. Consideration of air pollution was found to exist only in special cases where air pollution represents a major problem of regionwide social, economic and political concern. Even in such cases most of the effort was concerned with the abatement of an existing problem and not on the consideration of the influence of regional patterns of land use on air quality for future time periods.

Typically, air pollution is considered at a very superficial level of technical detail by planners and has never been a dominant factor in the development of a plan. Furthermore planners seldom interface to any significant degree with state and local air pollution control agencies, and until very recently little discussion of the available technology for projecting and analyzing the air pollution consequences of planning decisions has appeared in the planning literature. It was found, however, that interests in and concern for air pollution by planners is growing rapidly both as a consequence of the concern of the general public for environmental matters and in response to the requirements of state and federal legislation requiring the submission of environmental impact statements for proposed land use developments.

One of the dominant reasons for the lack of consideration of air pollution in the planning process is that air pollution has not been a significant problem historically and has not been of highest concern politically. Consequently, air pollution ranks very low in terms of priorities within the planning process relative to such issues as employment, economic development, housing and social needs. The second major constraint to the consideration of air pollution is the fact that planning agencies typically do not have staff personnel with appropriate backgrounds and technical training and skills in air pollution, do not have the required data base nor access to the required analytical tools to project air quality resulting from proposed future land use plans, and generally do not have the resources required to develop such capabilities. A number of other factors of lesser importance have also contributed to the lack of consideration of air pollution in the planning process. For example, planners prefer to view a region as a system of interacting elements of which air pollution is only one. Consequently planners are reluctant to permit a single element, such as air pollution, to have a dominant role in the development of a plan. Other constraints of a more practical nature result from the lack of a clear distinction between the responsibilities of the planner for abatement of air pollution problems in the long term and those of air pollution control officials. Finally, it was observed that the power base of planning agencies is usally quite limited, and consequently planning projects that involve large scale land developments, where the influence of air pollution considerations would be greatest, are most vulnerable to short term political and economic pressures often contrary to air quality goals.

From the results of the survey it was concluded that a critical need exists for methodologies and analytical tools which can be used by planners to make air pollution projections and to analyze the consequences of land use plans in terms of meaningful air pollution criteria. It was concluded that most of the routinely collected land use and transportation planning data are applicable to the derivation of source emission inputs to an air quality projection model, although considerable additional computations and processing probably will be required to transform such data into an appropriate format for input to the model. In addition, however, planners will be required to collect and work with a significant amount of totally new kinds of data in order to consider air pollution in the planning process. Furthermore it was concluded that a computer-based tool for the analysis of air pollution would be appropriate for planning agencies for determining air quality associated with large scale regional developments if this tool can be linked directly to the routine planning process and to the routinely collected data sets.

It was also concluded that to be of general use to planners, the methodologies should permit the planner to evaluate and rank alternative plans based on quantitative air quality evaluation criteria or indices. Furthermore, the methodologies should permit both a rapid assessment of plans at a low level of detail and a more detailed and comprehensive analysis of air quality impacts. Finally, it was concluded that there is a definite need for procedures and guidelines for considering air pollution at the initial phases of plan synthesis which would indicate how to locate land use activities or to modify urban forms in ways that will improve air quality.

1.3 Summary of Procedures for Considering Air Pollution in the Planning Process

In response to the general requirements identified in the survey of planning agencies, a methodology was developed that would permit planners to incorporate air pollution considerations within the planning process. The elements of this methodology consist generally of a set of procedures for collecting, processing and interpreting land use and other input data; a set of procedures for generating air quality information from the input data; and a set of procedures for the evaluation and ranking of alternative land use plans. This combination of methodologies, procedures and analytical tools represents a system for the analysis of air pollution that has been designated as the AQUIP System (Air Quality for Urban and Industrial Planning).

The AQUIP System is a computer-oriented set of procedures involving the planner in an iterative cycle of plan evaluation and modification consisting of the following basic steps:

1. The preparation of input data descriptive of the land use or transportation plan;
2. The conversion of this data into pollutant emissions data;
3. The prediction and display of mean ambient pollutant concentrations within the area of interest;
4. The evaluation and ranking of the plan with respect to other plans through analysis of air quality contours and the computation of quantitative measures of impact; and
5. The subsequent modification of the plan or the input data and the repetition of the process.

Of these five steps the first and last require the direct involvement of the planner to specify and manipulate planning data, to assess the degree to which a plan satisfies the planning objectives and constraints, and to specify changes to the plan as deemed necessary. The remaining steps involve directly the use of computer-based models and data management programs to perform the required air quality projections and data calculations.

The procedures developed for the analysis of air quality associated with land use plans are based principally on the evaluation and ranking of specified alternative land use plans in terms of impact on air quality on a region-wide geographic scale and in terms of annual and seasonal average pollutant concentrations. Furthermore the evaluation of air quality associated with a plan focuses on the analysis of four items:

1. The degree of compliance with ambient air quality standards;
2. The degree of impact on regional levels of air quality;
3. The degree of impact on specific receptors or land use categories which are especially sensitive to the effects of pollutants; and
4. The indication of ways to modify plans to improve air quality.

Procedures for examining compliance with air quality standards are straightforward and involve the calculation of projected air quality contours over the planning region. The maximum values of predicted air quality levels are then compared with the appropriate ambient air quality standards.

Procedures for examining the impact of land use plans on regional air quality are based first on the examination of spatial patterns of air quality, and secondly on the calculation of quantitative measures of impact for each pollutant. The examination of the isopleth contours of pollutant concentrations over the planning region indicates the location of regions of low and high pollutant concentrations, and also permits the visual examination of the influence of the type, location, and intensity of land use activities on the air quality contours. The calculation of impact measures permits the quantitative assessment of the impact of alternative plans on regional air quality and the comparative evaluation and ranking of the alternative plans.

An especially important aspect of the analysis and evaluation of land use plans is the analysis of impact of air pollution levels on specific high risk receptors and land use categories. The analysis procedures are based both on the examination of the location of critical receptors relative to air quality contours and on the calculation of quantitative measures of impact.

Procedures for plan modification using the AQUIP System consist of general guidelines based on the tabulation of the annual emissions per acre for the different land use categories analyzed for the Hackensack Meadowlands. Such data are used to identify land use categories which produce significant impacts on regional air quality levels and contours when moved within a plan, and land use categories which can be relocated within the plan without any substantial impact on regional air pollution concentration patterns.

1.4 Summary of Methodologies for Plan Evaluation and Ranking

The procedures developed for the evaluation and comparative ranking of alternative land use plans were based on the interpretation of three basic types of information: land use data, air quality data, and air quality criteria. The basic methodologies developed for plan evaluation and ranking consist of procedures for the analysis of air quality on a regional scale and for the analysis of air quality impact on specific land use categories through both the calculation of quantitative measures of impact and the graphical display and analysis of the spatial distribution of air quality contours. The analysis of spatial patterns of air quality can be carried out by calculating isopleth contours of pollutant concentrations, but their interpretation relies largely on visual examination and subjective judgment rather than on quantitative analysis. On the other hand quantitative impact measures permit analytic evaluation, but tend to subdue the physical and intuitive interpretation of the results. Consequently the key issue involved in the development of procedures for plan evaluation and ranking concerns the role of subjective judgment on the part of the planner. More specifically, the final interpretation of such quantitative data and its meaning in terms of impact and importance relative to other planning issues is one based entirely on subjective judgement.

In this study the quantitative measures of impact which were found to be most useful and meaningful in both plan evaluation and ranking were 1) measures of integrated receptor exposure and 2) measures of average receptor exposure. The integrated receptor exposure for a given plan is calculated by superimposing an arbitrary grid system on the planning region, forming the product of the number of receptors per grid cell times the pollutant concentration within the grid cell, then summing this product over all grid cells within the planning region. This impact measure physically represents an indicator of the cumulative values of receptor exposures within the plan. By contrast, the average receptor exposure impact measure is calculated from the integrated exposure measure by dividing the resultant integrated exposure measure by the total number of receptors within the plan. Consequently, the average exposure measure has units of pollutant concentration, and physically represents an indicator of the average concentration to which any given receptor within the plan will be exposed.

The specific receptors investigated in terms of these quantitative measures of impact were people and land. Two categories of people receptors were examined: total population, and students. Four categories of land were examined: total land area of the planning region, residential land area, open space land area, and the combination of commercial and industrial land area. In the analysis of the Hackensack Meadowlands plans, the average total area exposure was examined as the primary measure of regional air quality and the average population exposure impact parameter was examined as the principal measure of impact on critical receptors. However, quantitative impact measures were calculated for all combinations of pollutants and receptor categories. In addition the AQUIP System permits a significant amount of flexibility in defining and calculating other quantitative measures of impact, and in specifying air quality criteria other than ambient air quality standards for use in the evaluation.

The specific requirements for the quantitative ranking of alternative land use plans differ slightly from the requirements for the analysis and evaluation of plans. The basic need for plan ranking is to generate a single number, or ranking index, which can be calculated for each plan to permit the relative ranking of the plans. This ranking index may be associated with the impact of a single pollutant, thereby allowing a pollutant by pollutant comparison and ranking, or it may be associated with the combined impact of all pollutants, i.e., a multipollutant air quality index.

Although it is required that the ranking methodology be based on a formula in order to state the ranking criteria in quantitative terms, it is also clear that no ranking scheme is unique or absolute. In fact it is desired that the ranking scheme be sufficiently flexible to accommodate the subjective values of the planner and his particular circumstances in formulating the ranking index, and it is required that the results of the ranking methodology give reasonable agreement with known facts and the intuitive judgment of the planner.

A brief survey of the literature dealing with multipollutant air quality indices indicates that in spite of the fact that a large number of such indices have been proposed, some of which are in use, all exhibit some degree of difficulty in accurately characterizing the status of total air quality in terms of multipollutant impact, and few were found to be directly applicable to the ranking of land use plans.

Three specific ranking schemes were examined in detail to determine their suitability as a ranking index which would be meaningful and useful in the ranking of alternative land use plans. The methodology finally selected for use in the analysis of the alternative land use plans for the Hackensack Meadowlands is designated as the Normalized Impact Parameter Ranking Index and was devised as a compromise between the other two indices. The selected ranking index has the significant advantage that it overcomes certain pathological cases encountered in the use of the other two ranking indices, while preserving most of their advantageous features (see Section 5.3.3).

1.5 Conclusions from the Air Quality Analysis of the Alternative Land Use Plans for the Hackensack Meadowlands

A study was conducted to evaluate and rank the four alternative 1990 comprehensive land use plans for the New Jersey Hackensack Meadowlands District in terms of air quality criteria. The basic objective of this analysis was to demonstrate the procedures and methodologies developed for considering air pollution in the planning process through the direct application of such methodologies to the planning alternatives developed for the Meadowlands. Regional air quality concentrations for total suspended particulates (TSP), sulfur dioxide (SO_2), carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_x), were analyzed in terms of annual averages and summer and winter seasonal averages. The analysis also included the influence of sources outside the Hackensack Meadowlands (i.e., background sources) on air quality within the planning region.

The four specific plans analyzed in this study were developed by the Hackensack Meadowlands Development Comission (HMDC) and are designated as:

Plan 1 - The Master Plan
Plan 1A - Self-Supporting New Town
Plan 1B - Expansion of New York City Urban Core
Plan 1C - Trend Development Based on Current Zoning

The principal results of the analysis of these plans are summarized in the following paragraphs.

1. Annual average ambient air quality standards are met for the 1990 time period in all four plans for the Hackensack Meadowlands region for three pollutants: SO_2, CO, and NO_x. Annual average ambient air quality standards are exceeded for 1990 in all four plans for two pollutants:

particulates and hydrocarbons. The analysis also indicates that the background concentration levels for both particulates and hydrocarbons exceed ambient air quality standards in 1990.

2. Analysis of the air quality of plans on the basis of individual pollutants indicates that:

   a. For TSP, maximum concentrations exceed the standard in all four plans by a factor of approximately 2.5. Thus air quality is a critical problem and must be of concern to the planner.

   b. For SO_2, maximum concentrations are on the order of 55 to 60% of the standard. Furthermore the variation among plans in impact on average regional air quality is less than 15%. Thus air quality is not a major problem and the planner can be neutral (relative to regional air quality criteria) in choosing among the four plans.

   c. For CO, air quality is of major concern within Plan 1B, for which the maximum concentration is approximately 90% of the standard. Since maximum concentrations are less than 70% of the standard and variation in impact on average regional air quality is approximately 4%, the planner can be neutral in choosing among the remaining three plans.

   d. For HC, maximum concentrations exceed the standard in all four plans by a factor of approximately 12. Thus air quality is a critical problem and must be of concern to the planner.

   e. For NO_x, maximum concentrations are on the order of 65% of the standard, and variation in impact on average regional air quality is approximately 7%. Thus air quality is not a major problem and the planner can be neutral in choosing among the four plans.

3. Analysis of the total regional air pollutant concentration levels and spatial patterns for the four alternative plans shows a significant variation among plans for all pollutants except hydrocarbons. The quantitative ranking of plans in terms of the multipollutant impact on total regional air quality indicates that Plan 1 is best (that is, produces least average regional concentration levels), followed by Plans 1B, 1A and 1C, respectively.

4. The corresponding analysis of the impact resulting from regional air pollutant concentration levels and spatial patterns on sensitive categories of land uses and receptors (primarily population) shows a significant variation in impact among the four alternative land use plans. A quantitative ranking of the alternative plans based on consideration of a number of impact measures indicates that Plan 1 is best (that is, has the least average exposure to the specified classes of receptors), followed by Plans 1B, 1A, and 1C, respectively.

5. Background air quality levels represent a major influence on total air quality levels within the Hackensack Meadowlands planning region. Background air quality accounts for between 65% and 99% of total concentration levels within the planning region (depending on the specific pollutant), and completely dominates the spatial patterns of total air pollutant concentrations. The background air quality contours for all pollutants show a north-south orientation with concentrations increasing from west to east. The pattern of concentrations shows the strong influence of pollution from the New York

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City urban region on Hackensack Meadowlands air quality levels. Since a significant spatial variation in background air quality levels occurs over the Hackensack Meadowlands region, the relative location of land use activities becomes a significant factor in minimizing the contribution of the specific plan to regional air quality levels and in minimizing the impact of the resultant regional air quality levels on specific receptors and land use categories.

6. Since background concentrations represent such a high percentage of total air quality within the Meadowlands for any given plan, the resultant variation among plans in total air quality necessarily will be small. For example, the maximum observed variations among the four plans in average regional air quality occurs for SO_2 and is less than 15%. As a consequence land use planning may be regarded as an ineffective procedure for abatement of regional air pollution in the vicinity of major urbanized areas unless the planning region is sufficiently large that "background" concentration levels represent only a small percentage (for example, less than 50%) of total air pollutant concentration levels.

7. Analysis of the impact resulting from the alternative land use plans on regional air pollutant concentration levels and spatial patterns shows significant variations among plans due to: (1) the percent mix of land use categories; (2) the relative location of land use categories; and (3) the relative density or intensity of land use activities. The observed variations in regional air pollutant concentration levels and spatial patterns are found to be extremely sensitive to the percent mix of manufacturing and transportation related land use activities. Manufacturing influences

primarily particulates, SO_2 and NO_x concentrations, while transportation activities influence the CO concentrations. As a consequence, these land use categories should be located within a plan relative to the spatial patterns of background concentrations in order to minimize net impact on total regional air quality levels.

8. In the Hackensack Meadowlands planning region, all land use activities other than manufacturing and transportation have a negligible impact on regional air quality levels and spatial patterns and therefore can be located within a particular plan rather arbitrarily to provide minimum impact to specific critical receptors and land use categories. Since the degree of impact on critical receptors is especially sensitive to the relative location of the receptors within the plan, the relative location of critical receptors and land use categories represents an extremely important consideration in the formulation and evaluation of land use plans. For example, it is observed that those plans which rank best in terms of population exposure have residential areas predominantly located in the western portions of the Hackensack Meadowlands planning region where concentrations generally are at their lowest levels.

9. Regional air quality is relatively insensitive to the amount of open space within any of the four plans. A direct tradeoff from manufacturing to open space land use, for example, would be highly beneficial to regional air quality levels, not because of the addition of open space within the plan, but rather because of the deletion of manufacturing land uses.

10. The analysis of regional scale air quality considerations is not sufficient to assess microscale impacts (that is, variations in concentrations over short distances and short time periods). Consequently, caution is

urged in interpreting results of regional air quality impact analyses. Such analyses will indicate which choice of a land use plan minimizes the impact on regional air quality levels and on critical receptors, but may not indicate the existence of, nor provide a solution to, microscale impact problems.

2. INTRODUCTION

2.1 Relationship of the Task 3 Report to Other Study Task Reports

This report documents the results of the Task 3 studies undertaken as part of the Hackensack Meadowlands Air Pollution Study. This study of the air quality of the New Jersey Hackensack Meadowlands was carried out by Environmental Research & Technology, Inc. (ERT), under contract to the New Jersey Department of Environmental Protection and to the Environmental Protection Agency, Office of Land Use Planning. The general objective of this study was to develop a system of procedures (designated herein as the AQUIP System) to permit land use and transportation planners to incorporate in a meaningful way air pollution considerations into the planning process, both at the formative stages of plan development as well as in the detailed evaluation of already developed land use plans.

This Task 3 Report is oriented specifically toward describing the general procedures for considering air pollution in the planning process through techniques for the analysis of air pollution impact on regional air quality. The other major task reports for this study focus more specifically on: 1) the technical details of the methods for preparing emissions data (the Task 1 Report); 2) the technical description of the air quality prediction model and its validation (the Task 2 Report); and 3) the detailed description of computer programs and data management software, together with directions for their use (the Task 5 Report). Finally, the general planning guidelines based on the results of this study are documented in the Task 4 Report.

2.2 Task 3 Objectives

The general objectives of Task 3 were to develop procedures for incorporating air pollution considerations into the formulation and evaluation of alternative urban land use and transportation systems plans and policies; and to demonstrate these procedures through application to the evaluation and ranking of the 1990 comprehensive land use plans for the New Jersey Hackensack Meadowlands region.

In order to achieve these general objectives, the more specific work elements were to:

1. Survey planning agencies to determine the extent to which air pollution consideration have been or will be included in the planning process.
2. Develop methodologies (including the specification of required data, data processing, and use of analytic tools) to permit planners to assess the air pollution impact associated with land use plans.
3. Develop methodologies to permit planners to rank alternative land use plans.
4. Perform a regional air quality impact analysis of the four land use plans for the Hackensack Meadowlands for the 1990 time period.
5. Derive conclusions and guidelines of general applicability for considering air pollution within the planning process.

2.3 Structure of the Task 3 Report

This report contains the complete documentation of the work undertaken in Task 3, including a description of the methodologies developed, the data, the results of the analysis of the plans, and the conclusions derived from the analysis. Section 3 of this report documents the results of the survey of planning agencies. Section 4 documents the general methodology and procedures developed by ERT for incorporating air pollution considerations into the land use and transportation planning process. Section 5 documents more specifically the detailed procedures for plan evaluation and plan ranking in terms of air quality criteria. Section 6 documents the results of the air quality impact analysis, evaluation, and ranking of the four alternative land use plans for the Hackensack Meadowlands region.

3. SURVEY OF PLANNING AGENCIES

3.1 Objectives and Procedures

The survey of land use and transportation agencies served to fulfill several objectives essential to the development of appropriate and useful procedures for permitting planners to incorporate air pollution considerations into the planning process. The primary objective was to identify the extent to which planners currently consider air pollution in the planning process. The second objective was to identify those factors influencing the extent to which planners might consider air pollution considerations in future planning efforts. A third objective was to define the needs of planners for data, analytic tools, methodologies, and guidelines which would facilitate the consideration of air pollution in the planning process. The final objective was to utilize this information in the development of the AQUIP System.

The survey was carried out by interviewing both administrative and technical personnel within the urban planning and transportation system planning agencies. Agencies surveyed were selected to achieve a representative sample in terms of size, resources, staff skills, and scope of planning responsibilities. The specific agencies surveyed are listed in Appendix A. These include agencies at the state, regional, county, and city levels of government as well as private planning groups. Some are devoted exclusively to transportation systems planning while others are devoted to comprehensive urban and land use planning. These agencies also include some known to be active in the field of air pollution consideration as well as some known to have either little concern for or few problems with air pollution.

In the course of the survey, staff members of the agencies were

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interviewed on a variety of subjects. The survey included a review of current and past planning projects; a discussion of basic attitudes of the planners towards air pollution as a problem and as an issue in the planning process relative to the priorities of other planning issues and considerations; a discussion of constraining factors in the consideration of air pollution; a discussion of the internal resources, skills, and data available for considering air pollution; and a discussion of what planners would like to see in the way of methodologies, tools and guidelines for assistance in considering air pollution.

3.2 Summary of Survey Findings

As anticipated, the survey showed a wide variation in the extent of current consideration of air pollution in the planning process, and in the attitudes toward the priority and role of air pollution as a planning consideration. The principal findings of this survey are reported in the following sections, which deal with: 1) the extent of current considerations of air pollution; 2) the identification of constraints faced by planners in considering air pollution; 3) problems associated with the compatibility of available planning data and the data requirements for air pollution analyses; and 4) implications for the design of the AQUIP System based on results of the survey. Results of other recent surveys on the same subject have been reported by Hagevik[1] and by Van Nest and Hagevik[2]. Many additional articles reflecting the viewpoint of planners toward air pollution and other environmental considerations can be found in the planning literature[3,4,5].

3.2.1 Extent of Current Air Pollution Considerations in Planning Agencies

It was generally found that air pollution historically has not been an issue of primary consideration among planning agencies. Consideration of air pollution was found to exist only in special cases where air pollution represents a major problem of region-wide social, economic, and political concern. Even in these special cases, however, little detail was exhibited in the analysis of pollution consequences for future time periods. Most of the emphasis was placed on cleaning up an existing problem through source emission controls and regulations, and through conventional zoning control techniques to regulate land uses. Air pollution considerations in such cases are typically oriented toward the analysis of areas which are already largely developed rather than on areas of future development. Consequently, most current planning efforts have no significant consideration of the influence of regional patterns of land use on air quality for future time periods.

It was also found that the extent to which air pollution is given consideration in the planning process currently is largely related to the resources available to the planning agency in terms of staff size, skills, and scope of planning projects, as well as funds available for inhouse or consultant studies. In most cases where air pollution has been considered, federal funds have been involved to some extent, and most of the studies have been undertaken by university resources or by consultants.

It was found that attitudes of planners towards the relative importance of air pollution as a factor in land use planning varied widely. Most were sympathetic with air pollution as a problem and as an issue of concern, but many felt that it was a largely overplayed issue relative to other planning concerns, while others felt that it should be the responsibility of the air pollution control bureaus. As a general rule, it was found that little importance was attached to air quality as a planning criteria by planning agencies within regions where air pollution currently is not a problem, even though it potentially could become a significant problem because of expanding population and urban growth.

It was also found that state and local air pollution control agencies, rather than land use planning agencies, have demonstrated the most concern for air pollution on the regional scale. As a result of some of these major air pollution studies, air quality prediction models have been developed for the application to specific metropolitan regions such as Chicago, New York, Nashville, and St. Louis. However, in spite of the development of such modeling techniques, the use of these models in actual transportation and land use planning activities has been noted as an obvious application but never applied to the actual planning process. Furthermore, until very recently, little discussion of this available technology has appeared in the planning literature, and no significant attempts have been made to use the dispersion modeling techniques in the planning process for the analysis of air pollution impact.

Throughout the duration of this study, however, it was observed that attitudes among planners are changing rapidly and that there is a growing concern among planners for air pollution and other environmental considerations, a concern which is growing at least as rapidly as the concern of the general public for environmental matters. Much of this concern is in direct response to the legal requirements as set forth by the A-95 review process, by the National Environmental Policy Act of 1969 (for submission of environmental impact statements for proposed developments involving federal funding), and by Section 4(f) of the Department of Transportation Act of 1966, as amended in Section 18 of the Federal Aid-Highway Act of 1969. It was found, however, that in some agencies there is an attitude of reluctance in complying with such legal requirements because of the uncertainty of the interpretation of these requirements and because of the added effort and costs necessary to comply with these requirements. Consequently, it was generally found that planning agencies devote no more than the minimum essential effort to considering air pollution concerns.

3.2.2 Constraints to the Consideration of Air Pollution

Exploring the reasons for the lack of air pollution considerations in planning is important in determining the probable extent of future consideration by planners.

A dominant feature of the planning process is the allocation of limited regional resources to the solution of regional problems such as employment, social problems, economical development, and housing. Furthermore, the allocation of resources to the solution of these problems not only is based on the needs as perceived by the planning agency, but also very realistically is responsive to key political and economic pressures at play within the region. Consequently, it is not surprising that air pollution has not been ranked particularly high in terms of important issues for consideration within the planning process. In most cases, it has not been a significant problem historically and has not been of highest concern politically.

Perhaps the greatest constraint to the consideration of air pollution is the fact that planning agencies do not have staff with appropriate backgrounds and skills in air pollution, do not have access to the required analytic tools nor the data base required to project air quality resulting from proposed future land use plans, and generally do not have the resources required to develop these capabilities.

It was found that planners typically have not received formal training in considering environmental effects in general nor in considering air pollution effects in particular. Planners generally have only a limited understanding of air pollution terminology, air quality criteria, air quality standards, or the effects of different pollutants on health and plant life. Similarly they generally have very little understanding of what considerations are important in air pollution, and what analytic techniques are available for assessing air pollution impacts.

An equally significant constraint to the consideration of air pollution was observed to result from a general lack of resources within planning agencies. As a branch of state, county, or city governments it was observed that planning agencies generally have extremely limited funding and numbers of personnel, especially personnel with specialties in computers, modeling, and air pollution. Furthermore, there was a wide variation in the resourcefulness and initiative exhibited by planning agencies in seeking and acquiring federal funding to either develop inhouse skills or to engage outside consulting firms to perform detailed environmental studies.

Another constraint is that planners usually work with broad issues at low levels of detail. As a consequence, while the analysis of air pollution impacts of land use plans requires a high degree of specific detail concerning land uses and transportation facilities, there is a tendency among planners to treat air pollution at a broad scale and low level of detail. A related problem is imposed by the time frame of the planning exercise. It is clear that ideas concerning the content and relative location of land uses change rapidly in the development of the land use plan. In addition, it is evident that there is a large margin of uncertainty in projections made with respect to such concerns as future employment, population, social patterns, and life styles.

It was found that planners feel a great risk in committing resources to air pollution abatement through planning when there exists such uncertainty in terms of changes in future technology dealing with air pollution, changes in the attitude of the general public toward air pollution as a critical issue, and changes in the ordering of priorities of problems and issues within the planning region.

Furthermore, it was found that planners like to view a region as a system and are interested in knowing the relationship and tradeoffs that may occur between the consideration of various air pollution planning measures and other environmental concerns, such as water resources and quality, solid waste disposal techniques, and so forth. Planners generally are not content to look at air pollution alone, nor permit it to have a dominant role in the development of the plan.

Another constraint results from the current lack of a clear distinction between the responsibility of the planner for abatement of air pollution problems in the long term and that of air pollution control officials. It was found that many planners feel it is not within their jurisdiction to incorporate air pollution into the planning process but rather feel that more effective solutions could and should be achieved by direct control of emission sources through the air pollution control agencies and their powers of regulation and enforcement. Existing land use zoning laws present many difficulties in providing an effective mechanism for controlling air pollution.

An additional constraint on the consideration of air pollution is related to the power base of the planning agency. It was found that planning agencies with jurisdiction over large regions (for example, state, regional, and county agencies) typically have an extremely limited power base. On the other hand, in smaller jurisdictions where the planning agency has more autonomy and control over land uses (such as within cities or small tract developments) the planning region is too small or too highly developed for land use planning to be effective in influencing regional air quality. Consequently, in those regions having the most potential for land development and where the influence of air pollution considerations would be greatest, it was observed that the planning agency has least control over the implementation of a land use plan.

3.2.3 Data Problems

In order to be useful to the planner the methodologies and procedures developed for considering air pollution must be highly compatible with the procedures and the data normally used by planners. The consideration of air pollution analytically requires relatively specialized types of data, in particular meteorological data and source emissions data are required as inputs to the air quality prediction model.

The required meteorological data for air pollution analysis is available for most metropolitan regions from the National Climatological Center located in Asheville, North Carolina, in the appropriate format for input to the model. The more difficult problem is posed by the requirement to develop an emissions inventory for input into the model based upon planning data or data routinely collected by or available to planning agencies. The problem is compounded by the requirements to develop an emissions inventory projected to a future time period as specified by the plan. Existing emissions inventories, as developed by state and federal air pollution control agencies, are necessary for model calibration but are only partially useful in determining future emissions inventories, especially in the 20 to 30 year time frame of most land use and transportation planning efforts.

In computing an emissions inventory for input to the model, significant emission sources, such as power plants, are usually represented as point sources. One-dimensional distributed sources, such as roadways, are usually represented in terms of straight line segments or line sources. Finally, a large number of relatively small emission sources (such as residential dwelling units or surface street traffic) are typically represented collectively in terms of arbitrarily shaped polygons or area sources representing land use zones.

It was found that planners never collect nor work directly with emissions data. Furthermore, it was found as a result of the survey that planners seldom collect or use data related to major point sources in the form necessary for computing emissions (for example, projection data on the capacity, location, fuel use, and stack height for power plants and large incinerators). In most cases, however, such data are collected by and available from utilities, air pollution control agencies, and other government sources. It was also found that planners (especially transportation planners) have excellent transportation projection data, and that the majority of the data is in a format and at a level of detail sufficient for use in calculating line source emissions. Finally, it was found that the data required to calculate area source emissions are similar in format to the type of data most frequently collected and used by planners, but often lack sufficient detail to carry out the calculations.

For example, planning information tends to deal with industries by broad categories (e.g. by specification of SIC numbers) and rarely with the characteristics of a specific firm which influence the level of emissions at a particular location. The land use planner does work with parameters such as acres and lot coverage, which can yield an estimate of the number of square feet of floor space for a facility (essential for calculating fuel use), but seldom works with specific fuel use data, for example, the particular type and amount of fuel, or the percent used for process heating, or the method by which space heating is accomplished (such as central heating systems versus individual heating plants). On the other hand, it was found that some of the data currently collected by planners are very detailed, for example, projections of housing, employment, and population, but are not directly applicable to the calculation of emissions.

Consequently, it was concluded from the results of the survey that to a large extent, data collected by planners can be utilized to calculate the required emissions inventories. However, planners will be required to collect and work with new kinds of data in order to consider air pollution in the planning process. The subject of input data requirements and procedures for calculating emissions data from land use planning data is discussed fully in the Task 1 Report.

3.2.4 Implications for the Design of Air Pollution Consideration Methodologies

It was found that planners have considerable capabilities and backgrounds in mathematical modeling, data processing, and projection techniques. Planners work to a great extent with data tabulations as well as with maps and graphic representations of data, and they have available large amounts of current and projected land use and transportation data, often in the form of computer data files. Consequently, it was concluded that a computer based tool for analysis of air pollution would be appropriate for the larger planning agencies and those associated with large scale regional developments, especially if this tool can be linked directly to the routine planning process and to the routinely collected data sets.

Thus a further basic requirement for the design of the air pollution planning methodology is that it permit planners to work with available land use data to the greatest extent possible. Most of the routinely collected land use and transportation data appear to be applicable to the derivation of source emission inputs to the atmospheric diffusion model, although probably requiring considerable calculations and data processing to transform the data into an appropriate format for input to the model. Current transportation planning data appears to be highly compatible with the input data requirements for air pollution analysis. On the other hand, new kinds of data will be required by the planner, for example, source emissions data associated with major point sources such as power plants, incinerators, and industrial processes (especially when projecting to a future time period). Consequently, it is essential that the methodology permit the planner to work directly with land use data whenever possible, and that the additional types of data to be collected be clearly specified.

In terms of the more general requirements for the analytic methodology for incorporating air pollution considerations into the planning process, it was found that most planners expressed a desire to have more data and information available to them for considering the effects of air pollution resulting from land use plans in some quantitative way, although most preferred simplified tables and guidelines rather than a detailed and involved procedure for computing such information. Consequently, it was concluded that to be of practical use to planners, the methodologies developed must permit both a rapid assessment of plans at a low level of detail and a set of analytic procedures to permit a more detailed and comprehensive analysis of air quality impact. Such analytic tools should permit the planner to evaluate and rank alternative plans based on quantitative air quality evaluation criteria or indices. Furthermore, the procedures should provide planners with quantitative guidelines to indicate how to locate land use activities or to modify urban forms in ways that will improve air quality. Significantly it was found that there is as much interest among planners in considering air pollution during the initial synthesis of the plan as there is for considering the detailed impact analysis and evaluation of alternative plans. One of the most commonly expressed desires among planners was to have some indication of how to put together elements of the plan at the formative stages according to some principles of air pollution consideration.

Additionally, it was found that planners normally interpret regional values expressed by the general community and attempt to set goals in the planning process in accordance with such values. Furthermore, they are accustomed to injecting their own subjective value judgment in the process of developing a plan and allocating the resources of a region to achieve these goals. Consequently, any planning evaluation process must preserve the ability of the planner to make such value judgments.

Finally, it was found that the desired analytic methodology should be versatile enough to permit planners to apply it not only to the evaluation of a plan in terms of regional air quality analysis, but also in terms of impact analysis in the microscale. The need for techniques to examine the air pollution impact of specific plan elements and facilities at the microscale level of detail (especially during the plan implementation stage) in accordance with the requirements of environmental impact statements is widely recognized among planners. Similarly, the methodology should permit planners to investigate the relationship between air quality considerations and other design considerations, for example, the relationship between air quality and water quality, or the implications of plans to achieve good air quality on satisfying the transportation requirements of a region.

4. PROCEDURES FOR INCORPORATING AIR POLLUTION CONSIDERATIONS INTO THE PLANNING PROCESS

4.1 General Overview of the Methodology

The elements of the methodology to permit planners to incorporate air pollution considerations within the planning process consist of:

1. A set of procedures for collecting, processing, and interpreting input data.
2. A set of procedures for generating air quality information from land use data.
3. A set of procedures for the evaluation and ranking of alternative land use plans.

The combination of these procedures, methodologies, and analytical tools represents a system for incorporating air pollution considerations into the planning process. This system has been designated as AQUIP, a system for considering Air Quality for Urban and Industrial Planning.

The AQUIP System is a computer oriented set of procedures involving the planner in an iterative cycle of plan evaluation and modification as represented schematically in Figure 1. More specifically the AQUIP System may be thought of as being made up of the following basic steps or procedures:

1. The preparation of input data descriptive of a land use or transportation plan.
2. The conversion of this data into pollutant emissions data.
3. The prediction and display of mean ambient pollution concentrations within the area of interest.

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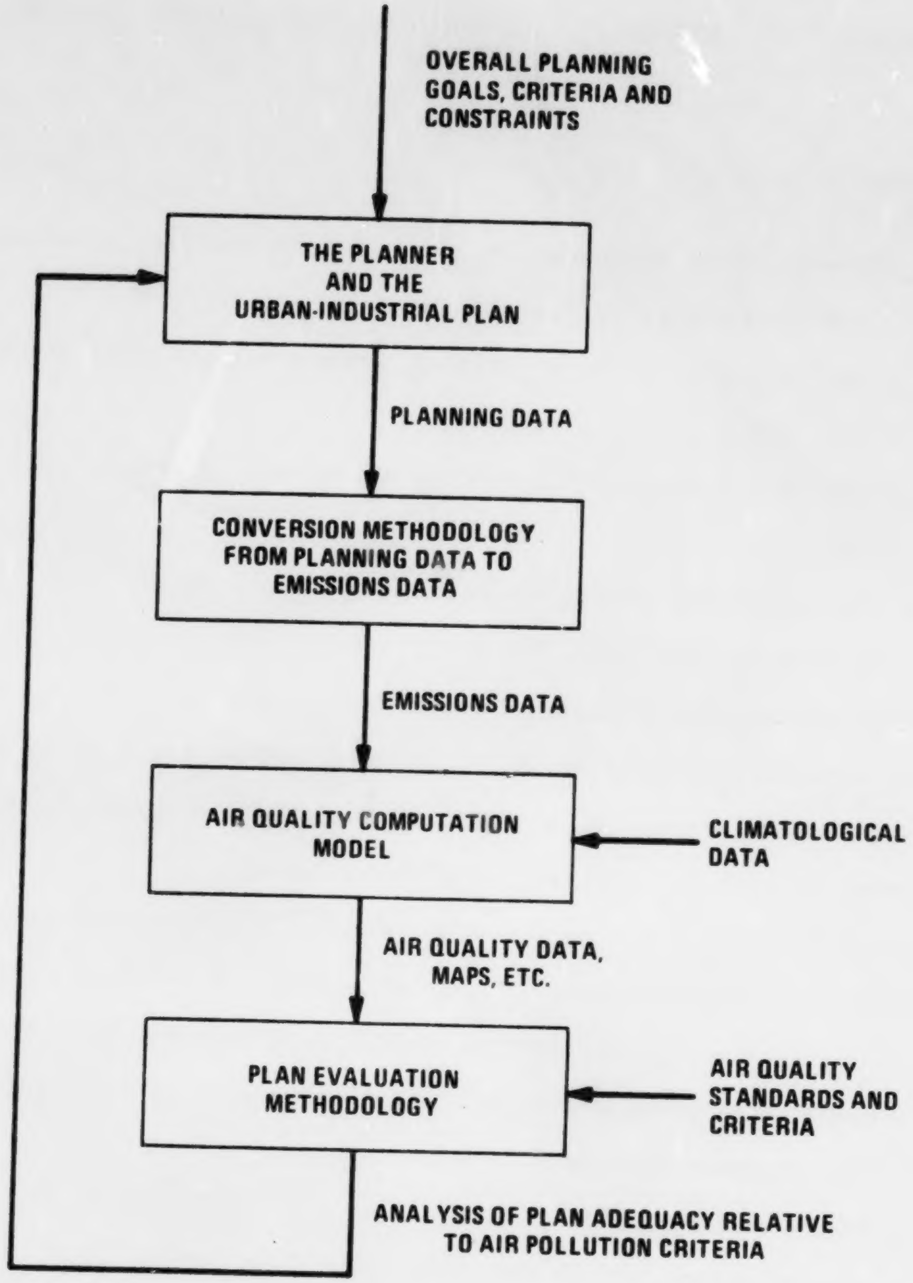
OVERALL PLANNING GOALS, CRITERIA AND CONSTRAINTS
THE PLANNER AND THE URBAN-INDUSTRIAL PLAN
PLANNING DATA
CONVERSION METHODOLOGY FROM PLANNING DATA TO EMISSIONS DATA
EMISSIONS DATA
AIR QUALITY COMPUTATION MODEL
CLIMATOLOGICAL DATA
AIR QUALITY DATA, MAPS, ETC.
PLAN EVALUATION METHODOLOGY
AIR QUALITY STANDARDS AND CRITERIA
ANALYSIS OF PLAN ADEQUACY RELATIVE TO AIR POLLUTION CRITERIA
6414

Figure 1 The AQUIP System Conceptual Design

4. The evaluation and ranking of the plan with respect to other plans through analysis of air quality contours and the computation of quantitative measures of impact.
5. The subsequent modification of the plan or the input data and repetition of the process.

Of these five steps, the first and last require the direct involvement of the planner to specify and manipulate planning data, to assess the degree to which a plan satisfies objectives and constraints, and to specify changes to the plan as deemed necessary. The remaining steps together form a model in which the techniques and methodologies are quantitatively embodied as self-contained computer programs.

A basic feature of the AQUIP System is that it permits the direct input of land use planning data. As a result it can be used to compute ambient air pollution concentrations related to specific land use activities. The primary outputs of the system are in the form of computer-generated maps and tabular listings of data. For example, computed concentrations for each of the pollutants may be displayed as isopleth contours and overlayed on base maps of the planning region, permitting a rapid visual correlation of air pollution concentration levels and spatial distribution patterns with the types and relative locations of land uses.

The heart of the AQUIP System is the mathematical diffusion model used to compute pollutant concentrations averaged over arbitrarily specified time periods. Typical time averaging periods for regional scale air quality analysis are seasonal and annual averages. The model is a version of the Martin-Tikvart Advection-Diffusion Model which has been modified by ERT to improve the accuracy of calculating concentrations over short transport distances and to improve flexibility in the use of the model.

A third essential element of the AQUIP System is the air quality data management and impact analysis software. In this portion of the system the user can specify arbitrary measures of impact based on manipulation of air quality data, emissions data, land use data, air quality standards, or any other basic data from the input data set. In this step correlations among such data sets can be tabulated or presented graphically, showing for example, the distribution of air pollution concentrations, emissions densities, impact parameters, land use densities, or any other subset of the basic data of interest to the planner. Furthermore, such data can be used to compare and rank plans in terms of air quality standards and criteria as specified by the planner.

The details of procedures for converting land use data to emissions data in formats required for input to the model are described in the Task 1 Report. The details of the air quality projection model and the procedures used for its validation are described in the Task 2 Report. The detailed description of the computer programs, the procedures for using these programs, and the interface between computer programs within the AQUIP System are described and documented in the Task 5 Report.

The objective of the remainder of this chapter is twofold: 1) to discuss the scope and level of detail of analysis appropriate to the consideration of air pollution within the planning process; and 2) to discuss the specific criteria, considerations and procedures essential to the analysis of air pollution within the planning process.

4.2 Classification of Air Pollution Considerations within the Planning Process

In considering the application of air pollution analysis to problems associated with land use planning it is necessary to match the analytical approach to the level of detail and scope of the particular planning problem. Of the many ways of classifying air pollution considerations, two appear most useful in characterizing the appropriate approach to the analysis of land use planning problems: these include the geographic scale of the analysis, and the stage of the plan design within the planning process.

4.2.1 Geographic Scale of Analysis

One of the more useful ways to differentiate problems for air quality analysis is in terms of the geographic scale of analysis. The characteristics of the problem fall conveniently into three categories: regional, corridor (or sub-regional), and microscale.

The analysis of air quality at the regional scale implies problems characterized by areas on the order of 50 to 100 square kilometers or greater. Air quality at such a scale of analysis is appropriately analyzed in terms of long-term time-averaged air pollutant concentrations, such as seasonal or annual averages. This scale is appropriate for the analysis of seasonal variations in air quality and the analysis of the influence of regional scale topographical features, synoptic meteorological conditions, and climatological conditions. This scale is also appropriate for the analysis of large-scale land developments, especially regional land use plans oriented towards a future design time period. Under such circumstances the accuracy of the described source emissions can be relatively broad scale so long as it remains commensurate with a level of accuracy appropriate to the planning process.

In particular, the level of analytical detail should be sufficient to detect changes in regional air quality due to major planning options in terms of the relative mix of land use types, the relative location of land uses within the plan, and the relative intensity of land uses. Furthermore, this scale of analysis permits the study of constraints imposed by the existence of already developed lands and facilities by incorporating into the analysis an inventory of background source emissions. While this scale of analysis permits the planner to overview regional air quality patterns and concentration levels, it cannot give sufficient detail in terms of time averages or spatial resolution of concentration patterns to analyze localized impacts within the plan (for example, variations in concentrations occurring over distances less than 1 or 2 kilometers, and over small time intervals such as a few hours).

The second geographic scale of analysis is designated as a corridor or sub-regional scale, and is particularly suited for the analysis of corridors along major roadway facilities up to distances of a few hundred meters from the road, or in the vicinity of sub-regional developments. This scale of analysis permits a greater level of detail in describing the source emissions and correspondingly permits a finer time and spatial resolution of pollutant concentrations. At this scale, however, the analysis begins to encounter problems of accuracy resulting both from localized influences, for example, industrial sources in the vicinity of the roadways, and from regional background concentration levels.

The third and most highly detailed level of air quality analysis is associated with the microscale analysis, and is appropriate to the description of very localized air quality impacts such as in and around roadways or in the immediate vicinity of buildings. Air quality analysis at this geographic scale and level of detail would be of interest to the planner in determining the impact of specific facilities at a given location, for example, plan view air quality contours in the vicinity of a major roadway intersection, or air quality concentrations in the vertical cross-section of a roadway. Such detail would permit the assessment of the relative impact of elevated, at grade, or depressed roadway configurations on air rights structures, or on commercial activities and residential areas set back from the right of way. This scale of analysis requires a highly detailed specification of source emissions and geometries. Because the local concentrations at this level are responsive to rapid changing meteorological conditions and source emissions configurations, the analysis at this scale usually examines only "instantaneous" concentrations resulting from a single specified set of meteorological and emissions conditions, typically representative of worst case and nominal situations. Although the state of the air in modeling concentrations over short time intervals and small distances is less advanced, nevertheless this scale of analysis is highly useful in the planning process, especially in selecting facility designs which minimize such localized impacts.

4.2.2 Stages of Plan Development

Although planning ideally is an ongoing process, nevertheless the development of a plan has three relatively distinct stages: the synthesis or initial design of a plan, the evaluation and detailed analysis of a plan and its alternatives to select a master plan, and the implementation of the adopted plan. At each stage the requirements for air pollution analysis are slightly different and represent a convenient method of classifying air pollution considerations in the planning process.

In the plan synthesis stage the air pollution analysis ideally should consider both regional air quality impacts and microscale impacts. First of all, in developing plans, many ideas are considered and rejected rather quickly. Plan alternatives are sketched on the basis of broad planning issues and their implications on the mix of land uses and their relative locations and densities. Thus the air quality analysis must permit a correspondingly rapid estimation of the impact of the land use plans on overall regional levels of air quality. A second need of the planner, however, is an understanding of the localized impacts of specific facilities or elements of the plan in order to mitigate local air pollution problems and to consider system effects. At this stage for example, the planner should know the regional impacts as well as the localized impacts on specific receptors and the results from alternative facility design concepts such as central heating systems, and the relative density of residential areas.

In the second stage the planning process will be attempting to analyze in some detail the aspects of the several planning alternatives in order to determine in more detail the implications of each in terms of such considerations as satisfying regional needs, development costs, economic feasibility, and environmental impact. In terms of the analysis of air quality, this longer and more detailed evaluation of the plan requires primarily an analysis of regional air quality to determine in detail the impact of the land use or transportation system plan on regional air quality levels. Thus at this stage, the appropriate air quality analysis is characterized by a more detailed evaluation and ranking of alternative plans, and by a process of trial and error in modifying plans to alleviate air pollution problems or to consider the tradeoffs between air pollution considerations and other planning issues. Analysis at this level of detail may require many months for completing the air pollution analysis and a substantial amount of detail in specifying land uses, their location, and other characteristics of the plan, such as power plant locations and operating characteristics.

During the plan implementation stage the primary requirement for the air quality analysis is to identify sub-regional and microscale impacts of proposals for specific land uses, such as housing developments, and for specific facilities such as roadways and incinerators. Such an analysis is necessary in the planning process at this scale to generate required environmental impact statements, to assess local impacts on critical receptors, to assess where to locate a specific facility, to determine whether to permit a given type of development, and to assess the efficacy of alternative designs for a specific facility in alleviating a localized air pollution problem.

4.3 Procedures for Consideration of Regional Air Quality

In the current study the scope of the effort was directed only toward the evaluation and ranking of alternative land use plans in terms of impact on regional air quality. Thus the procedures are concerned with the analysis of pollutant spatial distributions at the region-wide geographic scale and with annual and seasonal time-averages of pollutant concentrations.

Under these conditions, the procedures developed for the consideration of regional air quality must at a minimum permit the planner to determine for a given plan what air quality problems exist, where they are located, how serious they are, and how they can be reduced or eliminated. More specifically, the procedures developed in this study allow the planners to:

1. Determine whether the air quality resulting from a given land use plan is in compliance with appropriate ambient air quality standards.
2. Evaluate the impact of various plans in terms of spatial patterns and concentration levels, and in terms of calculated quantitative measures of impact on both regional air quality levels and specific receptors.
3. Rank alternative plans in terms of established air quality criteria.
4. Determine how to modify a plan in order to improve it relative to air quality criteria.

The general procedures for using the AQUIP System to accomplish these air quality analysis objectives are described in the following paragraphs.

4.3.1 Compliance with Ambient Air Quality Standards

Determining whether the air quality concentration levels resulting from a proposed land use plan will comply with appropriate ambient air quality standards is the most fundamental and direct method for considering air pollution in the planning process. These standards have been established by both federal and state laws and represent quantitative criteria which must be met. Values represented by these standards are based on the best available data concerning the effects of each pollutant on health, materials, vegetation, and visibility. Specifically "primary" standards reflect concern for impact on human health, while "secondary" standards reflect concern for impact on the general welfare (that is all other effects of air pollution impact on society). Consequently there is an implicit relationship between ambient air quality standards and air pollution impact.

Through use of the AQUIP System, air pollution concentration levels and spatial distributions resulting from a given land use plan can be tabulated and displayed graphically for each pollutant in terms of isopleth contours overlaid on a base map of the land use plan. This air quality data can be tabulated directly in terms of air quality averaged over each grid cell within the planning region, or the results can be output directly in terms of the ratio of the air pollution concentration to the ambient air quality standard. Through these tabular and graphic outputs the planner can determine which pollutants exceed standards, where the pollutants exceed standards, and by how much the pollutants exceed standards.

In addition, analysis of the output data can be examined to determine the contribution to total air quality resulting directly from the plan as well as to identify the background concentration levels resulting from the influence of emission sources located outside the planning region. Such an assessment of background air quality levels and the display of the spatial patterns of background air quality concentrations permit the planner to assess how much flexibility exists within the planning region in choosing elements of the plan in order to achieve other planning goals, such as more employment or more housing, without violating air quality standards. One of the key results of such an analysis is a determination of the degree to which the consideration of air pollution is important within the planning process.

4.3.2 Impact on Regional Air Quality

Procedures for examining the impact of land use plans on regional air quality are based first on the examination of the spatial patterns of air quality and, secondly, on the calculation of quantitative measures of impact of each pollutant on regional air quality levels.

The first required step is an examination of air quality contours (i.e. spatial patterns of pollutant concentrations) for background air quality over the region of interest. The resultant background spatial patterns and concentration levels will show first the basic average regional concentration levels in relation to air quality standards and secondly, the location of low and high pollutant concentrations within the planning region. This indicates initially where to locate elements of the land use plan in order to minimize peak total air quality concentrations (i.e. background concentrations plus plan contributions). For example, if the planning region is located within a highly urbanized region, background sources of emissions (especially those from industrial areas and transportation systems) will strongly influence pollutant concentration patterns within the region and hence influence the location and mix of land use categories within a plan to achieve compliance with air quality standards.

The second step in the general procedure for examining regional air quality is to determine total air quality contours for each pollutant for the alternative plans and to compare the variations in these contours among the different plans. A convenient working procedure is to prepare a plastic overlay for each plan showing the base map of land use categories. Placing the overlay onto the various pollutant concentration patterns (especially the computer-generated graphic displays) permits a visual examination of the influence of land use types, and the relative location and intensity of land use activities on air quality patterns.

As a final step, a quantitative assessment of the impact of alternative land use plans on regional air quality can be investigated by defining and calculating quantitative measures of impact. The primary utility for such measures of impact is in the comparative evaluation and ranking of alternative plans. Quantitative measures of impact appropriate to the analysis of regional air quality are discussed in detail in Section 5.

4.3.3 Impact on Receptors

The third major consideration in the procedures for analyzing the air pollution impact of land use plans is the determination of the impact of the resultant total regional air quality on specific land use categories and critical receptors.

Of major concern within the planning process are the effects resulting from the exposure of land use categories and critical receptors to various pollutants. For example, carbon monoxide (CO) has direct effects on human health resulting from short time exposures at high concentrations, but not on plant life. Hydrocarbons, on the other hand, have no direct health effects but do have very significant effects on plant life. Consequently, the planner can significantly modify the localized impact of various pollutants on sensitive receptors through the appropriate relative location of land uses within the plan. For example, since elderly, ill, or very young persons are considered to be more susceptible to the effects of pollutants than the general population, planners should be conscious of the locations of schools, hospitals, and nursing homes in the plan relative to pollutant concentration patterns.

As in the case for the analysis of impact on regional air quality, the procedures for the analysis of the impact of total regional air quality levels on receptors are based first on the examination of the location of critical land use categories and receptors relative to the spatial patterns of pollutant concentrations, and secondly on the calculation of quantitative measures of impact. The analysis of the spatial concentration patterns is achieved by overlaying the plan base map on the calculated pollutant air quality contours to correlate air quality concentrations with critical receptors. Furthermore, the impact analysis computer programs within the AQUIP System permit the user to define and calculate various types of quantitative correlations between land use data and air quality data, and thereby generate any desired measures of impact.

It is to be noted that there is no unique nor absolute method to evaluate the air quality impact of a plan on regional air quality levels or specific receptors. The analysis, for example, can examine the exposure of specific receptors, such as total land area, open space, school children, or total population, but each will result in a different measure of air quality impact. Each impact measure represents a value judgment of the planner concerning the relative importance of specific receptors and specific pollutants in evaluating a plan. The inclusion of value judgments in the definition of impact measures, however, is not necessarily detrimental to the procedures for plan evaluation. It merely indicates that the relative worth of a plan ultimately is a reflection of a human value judgment, a problem in plan evaluation which is not new to planners.

Since each of the pollutants has a different impact on different receptors, a final step in the plan evaluation procedures is to define and calculate a measure of the combined impact of several pollutants on a specific receptor.

Such a single overall measure of air quality impact forms the basis for the ranking of the different land use plans and is discussed in detail in Section 5.

4.3.4 Techniques for Plan Modification

The fourth and final essential step in the procedures for considering air pollution in the planning process is the method to guide planners in modifying plans in ways that will improve general regional air quality or will mitigate specific air quality problems. Through use of the AQUIP System to display air quality contours and to calculate impact parameters, the planner can identify the location and severity of air quality problems and analyze the character of these problems in terms of the types of receptors and pollutants involved. The methodology for plan modification makes use of this basic information to improve air quality.

In general a visual examination of the air quality contours should be made first to identify air pollution problems, identify which sources are the most likely contributors to the problem, and to identify which receptors are most seriously affected. Then based on this examination, critically affected receptors and land use categories should be moved to regions within the plan showing lower concentration levels.

If a more organized and systematic approach to plan modification to improve air quality is warranted in terms of the resources at the disposal of the planner, a number of more sophisticated analytical techniques can be devised. In particular, the AQUIP System can be used to compute: 1) sensitivity coefficients, 2) receptor oriented influence coefficients, and 3) source oriented influence coefficients.

Sensitivity coefficients represent the changes in air pollution concentration at a receptor point resulting from systematic changes in source emission characteristics. This provides a direct air quality relationship for a specific source-receptor pair.

Receptor oriented coefficients represent a set of data which, for a given receptor, identify those sources which contribute concentrations of greater than a specified amount or percentage at the receptor point. This data can be used by the planner in determining which sources to modify, while the sensitivity data indicates approximately how much of a change is required in a given source to achieve necessary reductions in concentrations at the receptor.

Source oriented coefficients, on the other hand, represent a set of data which, for a given source, identify the region within the plan over which the source contributes concentrations of greater than a specified level. This data in effect represents the influence region for the specified source under the specified meteorological conditions. This data, which can be displayed graphically, can assist the planner in determining where to locate elements of the plan to minimize overlapping regions of influence of major (but perhaps essential) sources.

These analytical influence coefficient data sets for plan modification are not included in the current version of the AQUIP System, although they can readily be incorporated into the system.

Instead the procedures for plan modification using the current AQUIP System have been derived empirically from the air pollution study of the Hackensack Meadowlands and are listed as planning guidelines and are fully documented in the Task 4 Report. A primary result of these guidelines is the listing of the annual emissions per acre for the different land use categories analyzed for the Hackensack Meadowlands (see Table 12, Section 6). On the basis of such data, those land uses which have a significant impact on regional levels of emissions and hence a dominant effect on regional pollutant concentration levels and air quality contours can be readily identified. The result is the identification of land uses which produce a significant change in regional air quality contours when moved within the plan, and a corresponding identification of those land use categories which have no significant impact on air quality contours when their location is moved within the plan.

As a consequence, these guidelines can be used: 1) to establish rapidly the emissions loading within a planning region due to a specified mix of land uses; and 2) to identify which land use categories can be relocated within the plan without a substantial impact on the regional air quality concentration patterns. The result is a set of guidelines by which the planner can locate heavy-polluting land use categories by the appropriate consideration of meteorological conditions (primarily prevailing wind directions) and by consideration of background air quality patterns and levels. The basic idea is to place heavy polluters at locations having least background concentration levels. Correspondingly, planners can locate other land use categories, especially those of high sensitivity to pollutant effects, in order to reduce localized impacts on such critical receptors.

These concepts for plan modification guidelines are described more fully in the Task 4 Report, and are illustrated by the results of the Hackensack Meadowlands impact analysis discussed in Section 6 of this report.

4.3.5 Shortcomings of the Procedures

One of the basic problems with the above described procedures for the evaluation of plans in terms of quantitative measures of impact is that such impact measures are surrogates for air pollution effects of more direct interest both to the planners and the general public. Specifically, one would like to know the direct relationship of pollutant concentrations to health effects, costs, material damage, aesthetic qualities of a region, economic and social consequences and so forth. Such relationships, however, are not presently well understood and basic information and data concerning health effects, costs, and economic consequences are scarce and often quite unreliable. As reliable cost and effects data become available, however, they can readily be included in the AQUIP System analysis procedures, primarily by incorporating them directly into the quantitative measures of impact.

A second basic problem related to the analysis procedures described above is that these procedures do not readily permit the generation of information and data showing the relationship between air pollution considerations and other issues within the planning process. In most cases such issues are to some degree interactive with air pollution considerations. For example, the relationship between solid waste problems and air pollution levels may be a direct function of the impact on water quality levels, depending upon alternative choices of techniques of solid waste treatment and disposal. However, further research and much more hard data are required before such systems relationships can be fully taken into account within the consideration of air pollution in the planning process.

A final problem related to the procedures for investigating regional air quality is that the resultant time averaging periods and geographic scale of analysis do not give adequate information concerning microscale impact problems. The regional air quality analysis, for example, gives no information on peak hour traffic conditions; the resultant peaking of concentrations over short distances and short time periods will not show up as a problem when averaged over longer time periods and larger distances. Thus, conclusions concerning the land use plan based on a regional scale geographic analysis with annual average concentrations must be evaluated and interpreted with extreme care. Although the resultant mix and location of land use categories for a land use plan may be selected in such a way as to minimize the impact on both regional air quality levels and critical receptors, nevertheless the regional scale analysis may not indicate the existence of, nor provide a solution to, microscale impact problems.

5. METHODOLOGY FOR PLAN EVALUATION AND RANKING

5.1 Introduction

The analysis of a land-use or transportation plan in terms of air quality criteria depends on three basic types of information: land-use data, air quality data, and air quality criteria. As discussed in the preceding chapter the general procedures for incorporating air pollution considerations into the planning process require the calculation and analysis of these data both in terms of spatial patterns of pollutant concentrations and their correlation with land uses, and in terms of quantitative measures of impact (either on general regional air quality levels or on specific land-use categories and high-risk receptors). The analysis of spatial patterns of air quality can be carried out by calculating isopleth contours of pollutant concentrations, but their interpretation relies largely on visual examination and subjective judgment rather than on quantitative analysis. On the other hand, quantitative impact measures permit analytic evaluation, but tend to subdue the physical and intuitive interpretation of results.

The evaluation and comparative ranking of plans is based on the interpretation of these types of data and analytical results. Such an evaluation would be complex and cumbersome without a systematic approach, and the ranking or ordering of results would be especially difficult without some means of expressing the results quantitatively. Consequently, because of the critical importance of this subject, the purpose of this chapter is to describe in more detail the characteristics and use of quantitative impact measures in plan evaluation and ranking. Since procedures for plan evaluation differ from those for plan ranking, they are discussed separately in

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the following sections. Specifically the section on plan evaluation summarizes the general evaluation procedures, identifies receptors and land uses of prime concern in the evaluation, and identifies the impact measures selected for the analysis. Similarly the section on plan ranking identifies some prior efforts to develop total (i.e., multipollutant) air quality ranking indices, describes the ranking index selected for this analysis, and summarizes the basic procedures for plan ranking.

5.2 Procedures for Plan Evaluation

5.2.1 Basic Requirements

In this study, plan evaluation is meant to imply the analysis and interpretation of air pollution impact for a single plan and the comparison of plans on the basis of single pollutants. In order to carry out the evaluation of a plan the procedures must permit the evaluation of both regional air quality impact and the impact on specific receptors. Furthermore, the plan evaluation methodology must incorporate some quantitative measure of these impacts both in terms of impacts from individual pollutants and in terms of the combined impact of several pollutants. Ideally, such quantitative impact measures should be relatable to some standard reference value, such as ambient air quality standards, in order to permit a convenient intuitive or physical interpretation of the calculated values.

5.2.2 Summary of Plan Evaluation Procedures

The basic methodology for plan evaluation consists of procedures for the analysis of air quality on a regional scale and for the analysis of impact on specific land uses and critical receptors through quantitative measures of impact and through graphical displays of the spatial distribution of air quality contours.

The essential steps in these procedures consist of:

1. The calculation and comparison of pollutant concentration levels with ambient air quality standards.
2. The correlation of air quality contours and concentration levels with specific land use categories, their relative location, and intensity of use.
3. The calculation of impact measures as defined in terms of regional air quality and in terms of impact on specific receptors.
4. The calculation and display of supplementary air quality or land use data, for example, the calculation of additional impact measures, or the display of the location of critical receptors.

The critical step in the plan evaluation is the calculation of air quality data, for example, the ratio of pollutant concentrations to ambient air quality standards for each pollutant at points within the planning region. Examination of isopleth contours of this ratio within the planning region thus indicates the location and size of regions which exceed standards, and the amount by which standards are exceeded for each pollutant. The specific steps for obtaining air quality and land-use data, and for generating contour maps and tabular data using the AQUIP System are discussed in detail in the Task 5 report, which describes the computer programs, their required inputs, the resultant outputs, and procedures for using these programs.

The further evaluation of the plan, however, is primarily concerned with the analysis of quantitative impact measures. A characteristic feature of the plan evaluation procedure is that it focuses on the impact resulting from each pollutant rather than from a combination of pollutants. This permits a comparison of impacts on various receptors on a pollutant by pollutant basis. Multipollutant impact measures are more useful for comparing and ranking alternative plans (as discussed in Section 5.3). The specific impact measures used for plan evaluation in the Hackensack Meadowlands air pollution study are described in the following paragraphs, and the analytic results and interpretation based on these impact measures are documented in Chapter 6.

5.2.3 Selection of Impact Measures

An essential element of the evaluation of land-use and transportation plans is the calculation and analysis of quantitative measures of impact on regional air quality and specific receptors. In general, the impact measure must be related to a specific plan, to a specific receptor or land-use category within the plan, and to a specific pollutant. Thus the impact parameter (IP) is a function of three variables: the plan, the receptor and the pollutant.

In this study the impact parameters which were found to be most useful and meaningful in plan evaluation were: (1) measures of integrated receptor exposure, and (2) measures of average receptor exposure. The integrated receptor exposure for a given plan is calculated by superimposing an arbitrary grid system on the planning region, forming the product of the number of receptors per grid cell times the pollutant concentration within the grid cell, then summing this product over all grid cells within the planning region. The general formula for the integrated receptor exposure impact parameter is

$$IP(j,k,l)_{ire} = \sum_i R_i(k,l)C_i(j,k) \qquad (5\text{-}1)$$

where

$IP\ (j,k,l)$ = impact parameter for pollutant j, plan k, and receptor l

$R_i\ (k,l)$ = number of receptors (or land-use area) in grid cell i for plan k and receptor l

$C_i\ (j,k)$ = mean predicted ambient concentration within grid cell i for pollutant j and plan k

j = specified pollutant

k = specified plan

l = specified receptor or land-use category

i = i^{th} grid cell within the planning region

ire = designation for integrated receptor exposure.

This impact parameter has units of number of receptors times pollutant concentration, and clearly is an indicator of the cumulative value of receptor exposure within the plan. Since this impact measure is sensitive both to the number of receptors and to concentration levels, it is likewise clear that the impact measure will be higher when larger numbers of receptors are exposed, just as it will be higher when higher concentrations exist. It is to be noted also that this exposure is based upon the calculation of the mean annual concentrations. Thus the exposure represents the mean concentration to which a receptor is exposed at any instant in time. The important distinction is that this impact measure is based on exposure rather than dosage, which can only be inferred based on an assumed time duration of exposure.

The second impact parameter, the average receptor exposure is calculated from the integrated exposure impact parameter simply by dividing the resultant integrated exposure by the total number of receptors within the plan. Thus the units of the average exposure impact parameter are units of concentration.

Physically, the average exposure is an indicator of the concentration to which any given receptor within the plan will be exposed on the average. However, since exposures are zero in regions of the plan where no receptors exist, it is to be noted that this impact parameter represents the average pollutant concentration only within those regions of the plan where receptors are located.

The choice of specific receptors or land uses for use in plan evaluation can be arbitrary and is largely a matter of judgment on the part of the planner and should reflect those issues which he considers most important. In the Meadowlands study the land-use categories and receptors examined were total land area of the planning region, population, students, residential land area, open space land area, and a combination of commercial and industrial land area.

An impact parameter based on total land area represents a good measure of impact on regional air quality. Since the total area of the planning region is fixed, the integrated and average exposure impact parameters differ only by a constant factor and thus both are representative of the mean pollutant concentration throughout the entire planning region.

Impact parameters based on population and student receptors are of interest in terms of health effects. Students, especially those in elementary grades, represent receptors highly sensitive to the effects of pollutants. An impact parameter based on hospitals and nursing homes is also of interest since the elderly and the ill are considered to be high risk receptors, but was not included in the analysis due to the difficulty in deriving information on this class of receptors from the given land use data.

An impact parameter based on residential land area is of interest since it is most representative of the basic conditions for which the ambient air quality standards were established; namely, areas where the general public has a high degree of access and high probability of long-term exposures. Residential area is of concern in terms of effects on health, plant life, materials, and aesthetics.

An impact parameter based on open space is of interest because of the special nature of this land use category. Open space typically denotes parks, wooded areas, recreation areas and playgrounds, and open water. The general public usually has free access to such areas, although time exposures within these areas may be somewhat limited. Thus there is some concern for aesthetics and for health effects on both human and wildlife populations. Of greatest concern, however, is the exposure of plant life to pollutants.

Commercial and industrial areas are of interest since they include such areas as shopping centers, roadways, and pedestrian malls, where the general public has free access, although exposure usually occurs for short time periods. Such areas also have large numbers of working personnel, although applicable industrial health and safety standards typically are much less stringent than ambient air quality standards.

From this large (and non-exhaustive) number of receptors, it is clear that selecting impact parameters most appropriate to the evaluation of a plan is a matter of judgment in terms of the specific plan and circumstances. In the analysis of the Hackensack Meadowlands plans, the integrated total area exposure was examined as a measure of regional air quality levels, and the average population exposure was examined as the principal measure of impact on critical receptors.

5.2.4 Other Analysis Procedures for Plan Evaluation

There is no limit to the number of correlations and impact measures that can be defined and applied to the evaluation of land-use and transportation plans. The impact measures described above for use in the Meadowlands air pollution study are obvious choices and are easily generated from the AQUIP System using readily available air quality and land use data. However, the AQUIP System allows a significant amount of flexibility in defining and calculating other measures of impact and in specifying air quality criteria other than ambient air quality standards.

As a specific example of an alternative (but supplementary) approach to plan evaluation, a quantity arbitrarily defined as a "land-use compatibility score" for a given plan was calculated for the Meadowlands plans. First, a "land-use air quality compatibility matrix" was constructed (as illustrated in Table 20 of Sec. 6.3). This matrix lists land use categories (or receptors) versus pollutants. Each element of the matrix represents in our judgement the relative sensitivity (or tolerance) of a particular land use or receptor to a given pollutant. For convenience of calculation and interpretation, the numbers in the matrix represent the ratio of the permissible pollutant concentration to the appropriate air quality standard. This matrix does not redefine air quality standards, but rather assigns a tolerance factor based on value judgement to each land-use category or receptor. For example, commercial and industrial land may be considered as being relatively insensitive to SO_2 effects and thus capable of tolerating SO_2 concentrations up to twice the SO_2 standard, whereas open space may be considered as being highly sensitive to effects of HC, and thus capable of tolerating hydrocarbon concentrations of no more than one-half the HC standard.

Then the AQUIP System software, primarily the IMPACT program, was used to: (1) calculate within each grid cell of the planning region the number of pollutants (from 0 to 5) which violated any one of these land-use air quality compatibility criteria, and (2) display graphically on the plan the spatial distribution of the number of violations per cell. This display shows the regions of the plan where more pollutants tend to violate the land-use compatibility criteria and thus indicate regions of more severe air quality problems. As a final step, the land-use compatibility score was calculated by summing the number of violations per cell over all grid cells within the plan.

Other useful analytic procedures to aid in plan evaluation include: (1) The calculation of sensitivities of air quality (or impact parameters) to changes in land-use type, location, or intensity; (2) the graphical display of the location and intensities of land uses within the planning region; and (3) the creation of yet other data sets, such as additional correlations between air quality and land-use data, which can be displayed graphically.

For example, in the analysis of the Hackensack Meadowlands plans it was found useful to display the spatial distribution of the intensity of the major land-use categories and to correlate visually land-use categories, locations, and intensities with air quality contours. It was also found useful to examine the influence of a few major facilities and to calculate the concentrations resulting from the specific facility. In particular, some limited sensitivity data were obtained for the location of a major incinerator within the Meadowlands region and for the influence of local roadways.

As practical working procedures for the plan evaluation it was found useful to construct a plastic overlay showing the boundaries, rivers, major roads, and outlines of land-use categories for each plan. This overlay was made at the same scale as all of the computer graphic outputs. As a result the single land-use map could be overlaid onto the dozens of air quality contour maps and impact parameter spatial distribution maps. For reference and correlation work it was also found useful to develop a color photograph of the plan itself at the same scale as the computer graphic air quality maps.

5.3 Procedures for Plan Ranking

5.3.1 Basic Requirements

The requirements for the ranking of alternative land-use plans differ slightly from the requirements for the analysis and evaluation of a particular land-use plan. The basic need for plan ranking is to generate a single number or index which can be calculated for each plan to permit the relative ranking of the plans. This ranking index may be associated with the impact of a single pollutant, thereby allowing a pollutant by pollutant comparison and ranking. The more common need, however, is to compare plans on the basis of a single ranking index representative of the total air quality resulting from the combined impact of all pollutants (i.e., a multipollutant air quality index).

As discussed previously in this report it is clear that no ranking index is unique or absolute. In fact it is desired that the ranking index be sufficiently flexible to accommodate subjective value judgments in the ranking methodology. It is required, however, that the ranking methodology be based on a formula in order to permit the ranking to be based on quantitative criteria precisely stated in objective terms. It is also required that the results of the ranking methodology give reasonable agreement with known facts and intuitive judgment.

Finally, it is not necessary to give special weighting to plans which do not meet air quality standards since the principal objective is to establish the relative ranking of plans. Consideration of the degree of compliance with standards is more appropriately the subject of the plan evaluation, where plans with serious problems in meeting standards would either be rejected or modified in some way to alleviate the problem.

5.3.2 Background on the Development of Multipollutant Air Quality Indices

Considerable attention has been devoted to the problem of characterizing the overall air quality associated with the combined influence of several pollutants. The common basic desire is to devise a single number (or index) calculated by a formula or other quantitative means which would represent a measure of overall air quality. Air pollution control agencies in many cities and states have attempted to devise such an index both as a means of conveying information to the general public and as a means of technically assessing the severity of air quality; for example, to indicate the inception of various levels of episode conditions. Such an index is useful (if not mandatory) in estimating the benefits on total air quality of control strategies which influence several pollutants to different degrees. The federal government has attempted to rank the total air quality in different locations (e.g., major cities) on the basis of such an index in order to aid in establishing priorities for its air pollution programs. The multipollutant air quality index has also been proposed for use in comparing total air quality resulting from different sources, and in establishing meaningful long-term trends in air quality for a region even when the pollutant mix is changing. Finally, such an index is essential in the planning process to rank alternative land-use and transportation plans.

Among the many indices in use or proposed for use, the simplest measure of total air quality involves the summation of individual pollutant emission weights[6]. The next level of sophistication generally involves the use of weighting factors based on air quality standards for combining pollutant emissions or concentrations. One such index is "Pindex" as developed by Babcock[7]. The original version of Pindex used emissions data for TSP, SO_X, NO_X, CO, and HC and included a sulfur oxides-particulate matter (SO_X-PM) synergism term and a provision accounting for the photosynthesis of oxidants. In this index, weighting (or tolerance) factors equivalent to the reciprocal of air quality standards were applied to each pollutant. In a revised version of Pindex [8], ambient concentrations (not emissions) were used, the SO_X-PM synergism term was removed, hydrocarbons were deleted as a pollutant, and tolerance factors were extrapolated from EPA standards to equivalent values based on 24-hour averages for all pollutants.

Similar indices have been devised by a number of air pollution control agencies, although most combine only two or three pollutants, primarily SO_X, PM, and occasionally CO and oxidants. For example, Fulton County (Atlanta), Georgia [9] uses an index which combines concentrations of three pollutants as fractions of their respective standards, and the (San Francisco) Bay Area Air Pollution Control District[10] uses an index which sums four pollutants (NO_2, CO, COH*, and oxidants) weighted by factors related to California air quality standards.

A number of other indices have been devised which combine pollutants based on power law formulas. For example, in an early effort Green[11] proposed an index based on based on SO_2 and COH in which the concentration for SO_2 was raised to a power and multiplied by a constant and added to a similar term for COH. A similar index has been used by the Province of Ontario[12,13], and more recently applied to the Sarnia, Ontario, petrochemical complex[14] in conjunction with synoptic meteorological forecasting. Another index, based on weighting factors related to air quality standards and involving a power law formula, has been proposed by the Oak Ridge National Laboratories[8,15], and has been used by the Knox County (Tennessee) Air Pollution Control Department[16]. Specifically, this index combines CO, SO_X, NO_X, TSP, and oxidants by weighting the ambient concentrations of each pollutant by the reciprocal of their respective EPA air quality standard (extrapolated to a 24-hour averaging period). The sum of these weighted concentrations is multiplied by a constant and then raised to a power such that all pollutants at their standards yield a combined index of 100.

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*Coefficient of Haze(for particulate matter).

A variety of other formulations have also been proposed[17,18,19]. For example, the Columbia-Willamette Air Pollution Authority uses an index based on the integrating nephelometer[20], which measures light-scattering and hence relates air quality to visibility rather than pollutant concentrations. In Osaka, Japan, several indices[21] for combining SO_2 and TSP have been investigated, including an index based on multiplying the highest values of SO_X and TSP observed during a day. In New York City the alert system[22,23] is based on several combinations of SO_2, CO, and COH. Prodehl and Lowry[24] have developed an index which describes geophysical potential for air pollution by predicting inversion severity based on vertical temperature gradients rather than on pollutant levels.

More sophisticated indices involving statistical measures of pollution levels have also been proposed[8,25]. For example, Fensterstock, et al[25] has proposed an index in which ambient pollutant concentrations are standardized to yield individual pollutant indices, and the resultant individual pollutant indices are weighted and summed to form a single total air quality index. This methodology may use concentrations which are taken from ambient monitoring data or are predicted by means of a diffusion model. The concentrations are converted into a standard statistical distribution with a preset mean and standard deviation. The resultant individual pollutant indices are assumed to be equally weighted, although values other than unity can be used. Likewise, the index can incorporate any number of pollutants although it has only been used to combine SO_X, CO, and TSP because of lack of available data.

In spite of these diverse efforts to develop multipollutant air quality indices, the great majority exhibit characteristics which limit their utility, meaningfulness, or general applicability. One of the problems is that most such indices are specialized to a locality, usually in order to take advantage of available sources of data and to reflect the most important local air quality problems. For example, most indices incorporate only a few pollutants, predominantly SO_2 and TSP (especially in industrialized regions). Likewise, one or more other pollutants such as CO, HC, or oxidants may be included depending on local problems. Data availability has been a particularly constraining factor since most regions have not had extensive ambient air monitoring networks, nor have monitored more than one or two major pollutants on a continuous basis. Furthermore, in some cases the indices have been based on specific monitoring instruments which may not measure pollutant concentrations directly.

In addition to these problems, a number of other problems of a more general nature occur which limit the utility of the proposed indices. For example, several basic problems are associated with the use of air quality standards as weighting factors: standards do not exist for all pollutants; standards are written in terms of different time-averaging periods for various pollutants; state and federal standards occasionally differ; and standards may be subject to change. Other problems are associated with the interpretation of values resulting from such indices. Indices referenced to air quality standards permit some degree of intuitive interpretation, but those based on arbitrary definitions and scaling factors are more obscure in meaning. Consequently, studies usually must be undertaken to establish empirically a relationship (i.e., correlation) between index values and observed severity of total air quality.

Another basic problem relates to the choice of data for use in the calculation of the index. Inputs based on maximum observed concentrations within a specified time period at a given monitoring sites are not as representative of regional air quality as data averaged over several monitoring sites and over longer time periods. Most indices are oriented toward assessing day to day air quality levels and only a few can be extended to longer time periods, for example, to assess seasonal and annual air quality. Furthermore, the number of pollutants that can be considered is generally limited to the major pollutants since few others are routinely monitored, and little is known about their effects, concentration levels, or criteria for evaluation.

A final problem is that none of the proposed indices relate directly to effects of prime interest; for example, the relationship of total air quality to health, economics, and aesthetics. Furthermore, such indices do not account for effects on specific receptors; for example, the specific influence of pollutant levels and distribution patterns on population.

5.3.3 Methodologies Considered for Plan Ranking

Of the many concepts for multipollutant air quality indices, only a few were considered to be applicable to the ranking of land-use plans. The methodology for ranking plans must, for example, have the capability of: (1) combining an arbitrary number of pollutants (provided evaluation criteria are available), (2) incorporating concentrations data representative of regional air quality (in particular, data from many points within the region averaged over seasonal and annual time periods), and (3) incorporating the influence of regional air quality on specific receptors. Furthermore, it is recognized that no ranking methodology is unique, and that none can yet incorporate pollutant effects of most direct interest, particularly health and economic effects.

On the basis of such requirements and constraints, several potentially useful ranking schemes were considered. In this section, three basic schemes representing the most viable candidates for a ranking index are described since all were considered to have both good and bad features, and since the final choice was based on value judgment.

In most general terms the ranking index is calculated for a given plan in terms of a formula which combines the weighted contribution of the different pollutants. This is represented by the following formula:

$$RI(k,l) = \sum_{j} WF(j) \; IP(j,k,l) \qquad (5\text{-}2)$$

where

$RI(k,l)$ = ranking index for plan k and receptor l

$WF(j)$ = weighting factor for pollutant j

$IP(j,k,l)$ = impact parameter for pollutant j, plan k, and receptor l

j = specified pollutant

k = specified plan

l = specified receptor or land-use category

This ranking index depends on the initial selection of an impact parameter of the type discussed in Section 5.2.3 (for example, average population exposure or integrated total area exposure). Such indices thus have the capability of incorporating effects on specific receptors. Other forms for both the ranking index and the impact parameter were considered, particularly power law formulas. These were rejected, however, since they complicated the ranking index without contributing to the meaningfulness of the results.

Consequently, the three ranking schemes finally considered reduced to a question of the form of the weighting function (i.e., how to combine the impact parameters for different pollutants). The three schemes are designated as:

1. The Relative Ratio ranking index.
2. The Pindex ranking index.
3. The Normalized Impact Parameter ranking index.

The characteristic formulas for the weighting functions for each of these ranking indices are listed in Table 1 and sample calculations of each index are illustrated in Table 2.

It was found that the first scheme, the Relative Ratio ranking index, is an especially good procedure for comparing plans on a pollutant by pollutant basis and was, in fact, used for such an analysis of the Meadowlands plans. It gives not only the relative rank of plans, but also an indication of the percent variation between plans in air quality as based on the specific impact parameter under consideration. Furthermore, results for the combination of all pollutants show good agreement with intuitively expected ranking results, especially those based on a visual examination of air quality contours. However, this index does exhibit a pathological case when an impact parameter for a specific pollutant and plan becomes an extremely small value relative to the other impact parameters (as illustrated in Table 2 for pollutant A, plan 1). This may occur either when one pollutant has very low concentrations for a specific plan, or when the number of receptors effected is very small for a specific plan. Since the weighting factor is formed

TABLE 1

ALTERNATIVE FORMS CONSIDERED FOR A PLAN RANKING INDEX

Ranking Index(1)	Weighting Factor
1. Relative Ratio(2)	$\frac{1}{n}\left[\frac{1}{\underset{k}{\min}\ IP\ (j,k,1)}\right]$
2. Pindex(3)	$\frac{1}{n}\left[\frac{1}{AAQS\ (j)}\right]$
3. Normalized Impact Parameter(4)	$\frac{1}{n}\left[\frac{1}{\underset{k}{\mathrm{avg}}\ IP\ (j,k,1)}\right]$

(1) $RI\ (k,1) = \sum_j WF\ (j)\ \ IP\ \ (j,k,1)$

where

RI(k,1) = ranking index for plan k and receptor 1
WF(j) = weighting factor for pollutant j
IP(j,k,1) = impact parameter for pollutant j, plan k, and receptor 1
j = pollutant
k = plan
1 = receptor or land use category
n = number of pollutants

(2) $\underset{k}{\min}\ IP$ = minimum value of the impact parameters calculated for the plans (for a given pollutant and a given receptor).

(3) AAQS(j) = mean annual ambient air quality standard (or extrapolated equivalent) for pollutant j.

(4) $\underset{k}{\mathrm{avg}}\ IP$ = average value of the impact parameters calculated for the plans (for a given pollutant and a given receptor).

TABLE 2

SAMPLE CALCULATIONS FOR RANKING INDICES

Matrix Element	Matrix				Ranking Index
	Plan	Pollutant			
		A	B	C	
Impact parameters	1	1	20	4	--
	2	10	15	2	--
	3	16	25	3	--
Weighting Factors for:					
Relative Ratio (based on min IP)	--	1/1	1/15	1/2	--
Pindex (based on AAQS)	--	1/20	1/5	1/5	--
Normalized IP (based on avg IP)	--	1/9	1/20	1/3	--
Relative Ratio weighted impact parameters	1	1.0	1.33	2.0	4.33/3=1.44
	2	10.0	1.00	1.0	12.00/3=4.00
	3	16.0	1.67	1.5	19.17/3=6.39
Pindex weighted impact parameters	1	0.05	4.0	0.8	4.85/3=1.62
	2	0.50	3.0	0.4	3.90/3=1.30
	3	0.80	5.0	0.6	6.40/3=2.13
Normalized Impact Parameter weighted impact parameters	1	0.11	1.00	1.33	1.44/3=0.48
	2	1.11	0.75	0.67	2.53/3=0.84
	3	1.78	1.25	1.00	4.03/3=1.34

Numbers in this table are hypothetical.

from the reciprocal of the minimum impact parameter found among the plans (for the specified pollutant), the corresponding weighting factor for the pollutant involved in the pathological case will be extremely large relative to the weighting factors for the remaining pollutants. As a consequence, the ranking order of the plans will be entirely dominated by the single pollutant (as illustrated by pollutant A in Table 2). This in effect says that if a single pollutant has a very low concentration or impact in a single plan, then that plan gets ranked highest regardless of the consideration of other pollutants. This is an undesirable result since ideally such a circumstance should be discounted as a singular fortunate event and the ranking should be based on the relative impacts of the remaining pollutants. It is not expected that this pathological case will occur often, however, especially if background pollutant concentration levels within the planning region are high relative to concentration levels resulting directly from the plan.

The second ranking index is based on the work of Babcock[7,8] and hence is designated as Pindex, although the formula for the current plan ranking index is somewhat more generalized than that originally proposed by Babcock for an index of total air quality. Since the weighting factor for each pollutant impact parameter is formed by taking the reciprocal of the mean annual ambient air quality standard (or extrapolated equivalent) for that pollutant, the Pindex ranking index has the especially good feature that it relates the impact to an absolute basis or criteria, namely, air quality standards. Thus, the ranking index bears some relation to an established basis and hence at least some intuitive feeling for the meaning of different magnitudes of the index can be established.

However, because the impact parameter for each pollutant is normalized by its air quality standard, this index does not give a good indication of percent variation in air quality among plans. Furthermore, it exhibits a pathological case when a specific pollutant has exceptionally high concentration values relative to its air quality standard for all plans (as illustrated by pollutant B in Table 2. In such a case the contribution from that particular pollutant completely dominates the ranking index. Since the same thing happens for all plans, the result is that the ranking order for the plans follows exactly the order of the impact based on the single pollutant. Philosophically, this may be an entirely acceptable result to the evaluator since it says that if one pollutant exceeds standards in all plans by a large value, then that pollutant represents the most critical problem; and the best plan, therefore, is the one which has the least severe problem in terms of this singular (worst) pollutant. For this analysis it was concluded, however, that this pathological case should be avoided since it is not evident that the contributions of other pollutants should be ignored. For example, variations among plans in terms of the singular pollutant may be very small, while substantial variations may occur among plans for other pollutants. Furthermore, it is observed that this pathological case can occur with high frequency, especially for planning regions in the vicinity of urban areas, since it results from situations in which there are high levels of background concentrations for one or more pollutants.

The third scheme, the Normalized Impact Parameter ranking index, was devised as a compromise between the other two indices and has the significant advantage that it overcomes the difficulties encountered in the pathological cases for the other two ranking indices. In particular, this is accomplished by forming the weighting factor for each pollutant impact parameter by taking the reciprocal of the average impact parameter for all plans being considered. In other words, once the impact parameters are calculated for each plan for a specific pollutant, the average value is calculated, and its reciprocal used as the weighting factor for the specified pollutant. The process is then repeated for the remaining pollutants (see Table 2). As a consequence of using these weighting factors, the results of the ranking methodology are much less sensitive to the conditions which lead to the pathological cases of the other ranking schemes, as illustrated by the sample calculations in Table 2.

For example, if one plan and one pollutant yield a small impact parameter, then this term contributes very little to the total ranking index since it will be divided by the average impact parameter for the various plans rather than by the minimum impact parameter. Thus the weighting factors effectively discount this situation which led to the pathological case for the Relative Ratio ranking index. Furthermore, it is observed that the Normalized Impact Parameter ranking index preserves the same relative ratios among plans when ranked on a pollutant by pollutant basis as the Relative Ratio ranking index. However, it does not preserve the same relative ratios for combined pollutant rankings as the Relative Ratio index, although it does preserve the same relative ranking of plans.

Likewise, as illustrated by pollutant B in Table 2, if one pollutant has extremely large impact parameter values for all plans relative to its air quality standards, then the use of weighting factor based on the average value of these impact parameters preserves the relative differences among plans for the pollutant, while preventing it from dominating the ranking index as happened in the pathological case for the Pindex ranking index.

Under such conditions the other pollutants are weighted more heavily than in the Pindex method. It is to be noted, however, that the Normalized Impact Parameter ranking index does not yield numerical values which can be intuitively related to an absolute scale of reference as does the Pindex ranking index.

5.3.4 Summary of Plan Ranking Procedures

On the basis of the relative merits of the three basic ranking indices considered in the previous section for use in the methodology for plan ranking, the Normalized Impact Parameter ranking index has been selected for use in calculating the relative ranking of plans.

The specific procedures adopted for ranking of alternative land-use plans include the following steps:

1. Select or define the measure of impact (impact parameter) of interest to serve as the basis for the evaluation.
2. Calculate the quantitative measure of impact for each plan and each pollutant. This can be done either by hand calculations based on the air quality and land-use data generated previously from the AQUIP System for the plan evaluation or can be programmed and calculated directly by the AQUIP System.
3. Tabulate the results of the calculations of the impact parameter for each plan and each pollutant. It is to be noted that no maps result since the data has no inherent spatial distribution characteristics.
4. Examine the ranking of plans on a pollutant by pollutant basis. To do this, the above-tabulated impact parameter data can be used to calculate for each plan the Relative Ratio ranking index as

described in the previous section, showing both the relative rank of plans and the percent variation in air quality among plans for the given pollutant.

5. Examine the ranking of plans on the basis of the Normalized Impact Parameter ranking index for the combination of pollutants. This can be done by calculating values for the ranking index for each choice of impact parameter either manually or with the AQUIP System. The resultant values of the index for each plan form the numerical ranking of the alternative land-use plans.

6. Repeat the procedure for ranking plans on the basis of combined pollutants for different impact parameters in order to determine whether different impact parameters cause the ranking of plans to change.

7. As an optional step, rank plans based on the calculation and evaluation of other indices, for example, Land use/Air quality Compatibility Scores. Such Land-use Compatibility Scores were not used as a formal basis for plan ranking in the Meadowlands study primarily because the procedure is too complex and the meaning of the ranking score is somewhat obscure and not readily relatable to experience and intuition. Such results were used, however, to provide useful auxiliary information in the plan evaluation and ranking process.

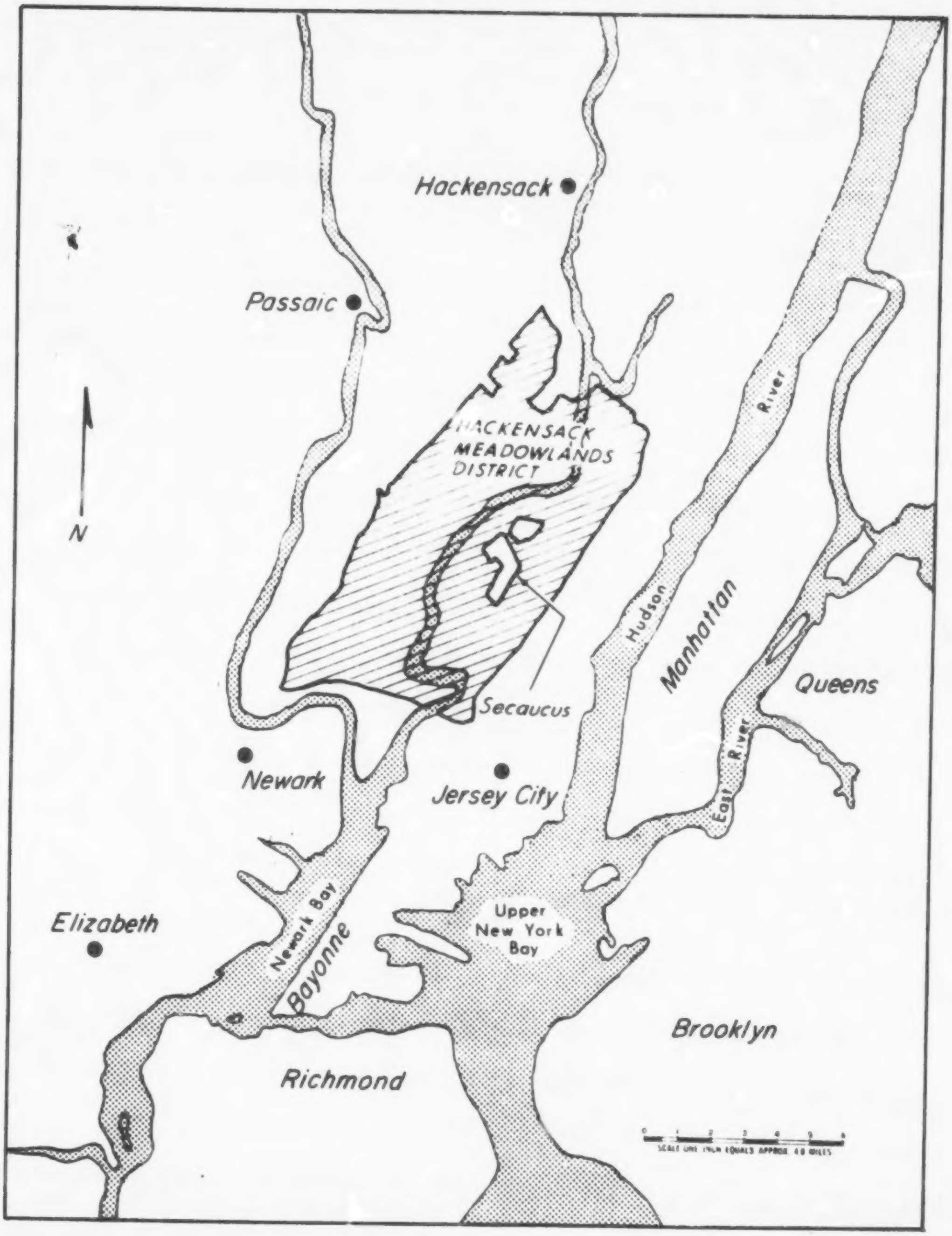
6. AIR QUALITY ANALYSIS FOR THE HACKENSACK MEADOWLANDS

6.1 Objectives of the Analysis

This section documents the results of a study conducted to evaluate and rank in terms of air quality criteria the four alternative 1990 Comprehensive Land Use Plans for the New Jersey Hackensack Meadowlands planning region. The basic objective of this analysis was to demonstrate the procedures and methodologies developed for considering air pollution in the planning process through the direct application of such methodologies to the planning alternatives developed for the Meadowlands. Regional air quality concentrations for particulates (TSP), sulfur dioxide (SO_2), carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_X), were analyzed in terms of annual averages and summer and winter seasonal averages. The analysis also included the influence of sources outside the Hackensack Meadowlands (i.e., background sources) on air quality within the planning region.

6.2 Summary of Plan Characteristics and Data

The New Jersey Hackensack Meadowlands District is a tract of land measuring approximately four miles by eight miles extending in a north-south direction along the Hackensack River. As shown in Figure 2, the Meadowlands is located at the hub of the New York - New Jersey metropolitan area. Within a five-mile wide zone around the Meadowlands is Manhattan immediately across the Hudson River to the east, Jersey City and Newark to the south, Paterson and Passaic to the northwest, and Hackensack to the north.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East River
Upper New York Bay
Elizabeth
Newark Bay
Bayonne
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SCALE ONE INCH EQUALS APPROX. 4.0 MILES

Figure 2   Location of the Hackensack Meadowlands District

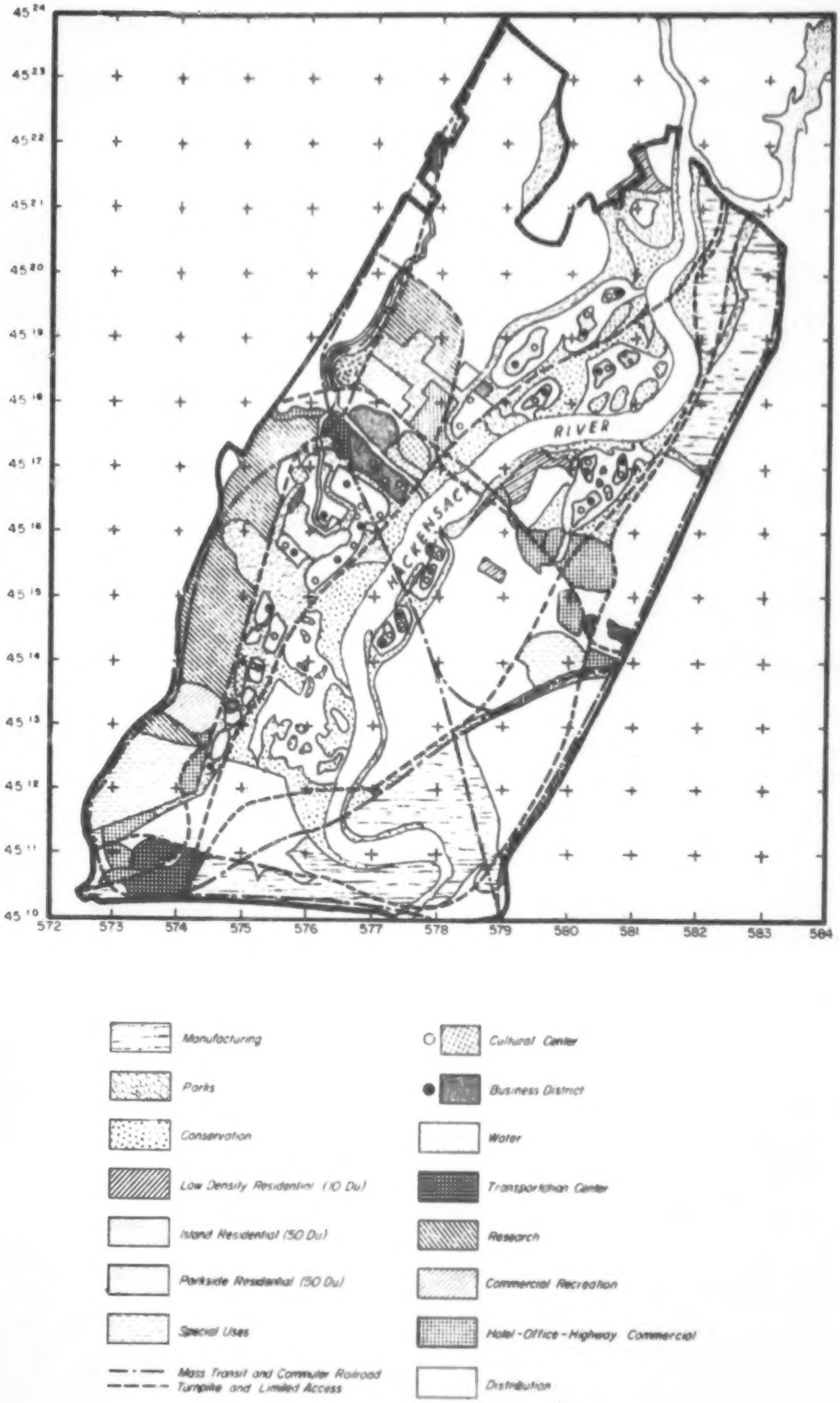
Today, the Hackensack Meadowlands consists largely of meadows, marshes, and salt-water swamps. Of its nearly 20,000 acres only 7,000 are committed to permanent uses. These consist largely of transportation networks (highways, railroads, and an airport), distribution centers (freight terminals, warehouses, storage tanks, and utility transmission lines), and solid waste disposal (over 30,000 tons per week from more than 100 municipalities.)

In 1968 the New Jersey legislature passed the "Hackensack Meadowlands Reclamation and Development Act"[26] creating a commission having the authority to prepare, adopt, and implement a master plan for the orderly development of the district. As a consequence, a number of alternative comprehensive land use plans have been prepared to compliment previous development in the district and to correct existing imbalances in regional land uses. Planners of the Hackensack Meadowlands Development Commission (HMDC) envision developing the Meadowlands in order to provide more than 300,000 jobs and homes for some 185,000 persons by 1990 while preserving nearly 5,000 acres for conservation land and open space.

The four specific plans analyzed in this study were developed by the HMDC and are designated as:

Plan 1 - The Master Plan[27]
Plan 1A - Self-Supporting New Town
Plan 1B - Expansion of New York City Urban Core
Plan 1C - Trend Development Based on Current Zoning

The original plans are in color to distinguish between the many activities. They are presented here in black and white (Figures 3 through 6) - the master plan is presented in color in reference 27.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HACKENSACK
RIVER
Manufacturing
Parks
Conservation
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Island Residential (50 Du)
Parkside Residential (50 Du)
Special Uses
Mass Transit and Commuter Railroad
Turnpike and Limited Access
Cultural Center
Business District
Water
Transportation Center
Research
Commercial Recreation
Hotel-Office-Highway Commercial
Distribution

Figure 3 Alternative Meadowlands Land Use Plan No. 1-The Master Plan

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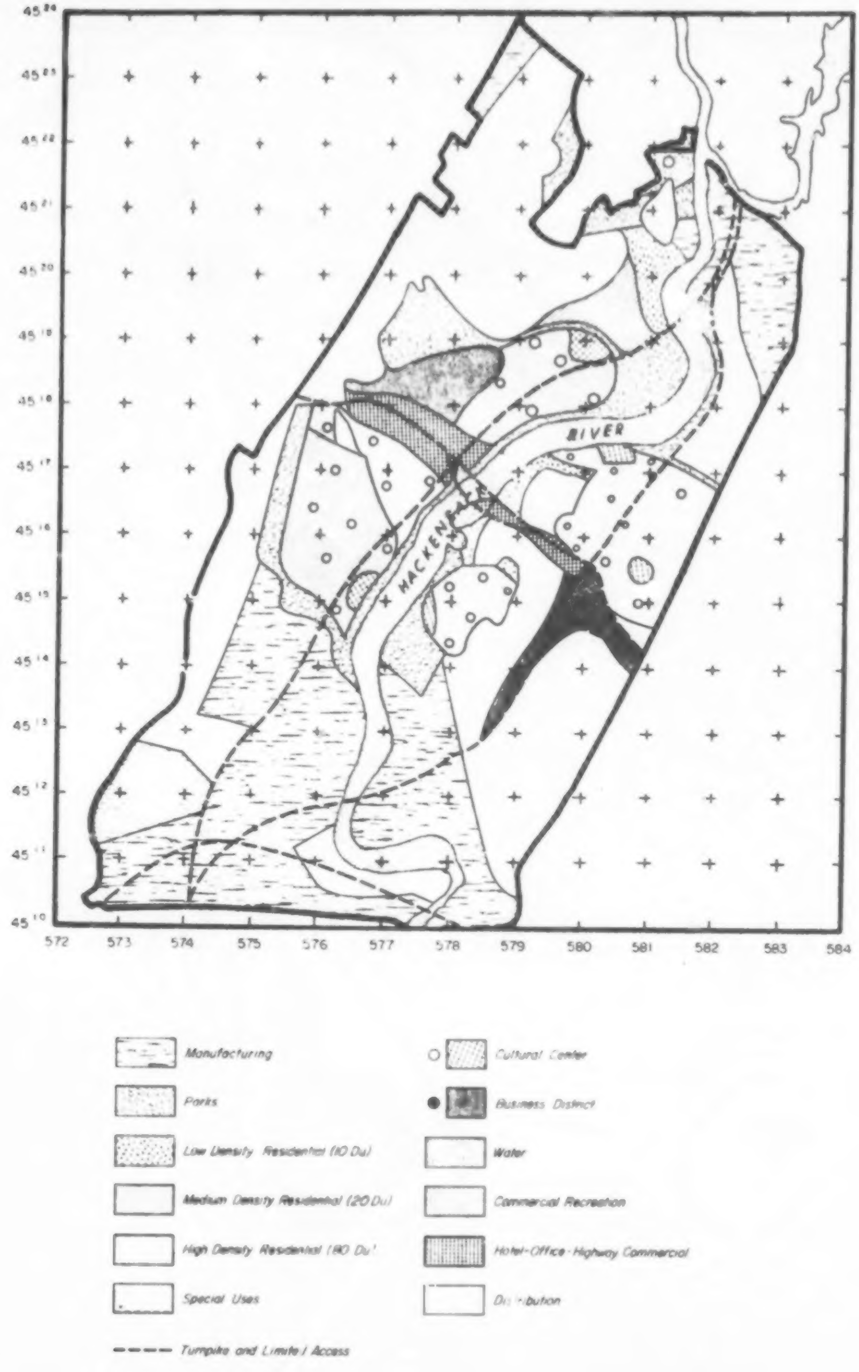
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RIVER
HACKENSACK
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Parks
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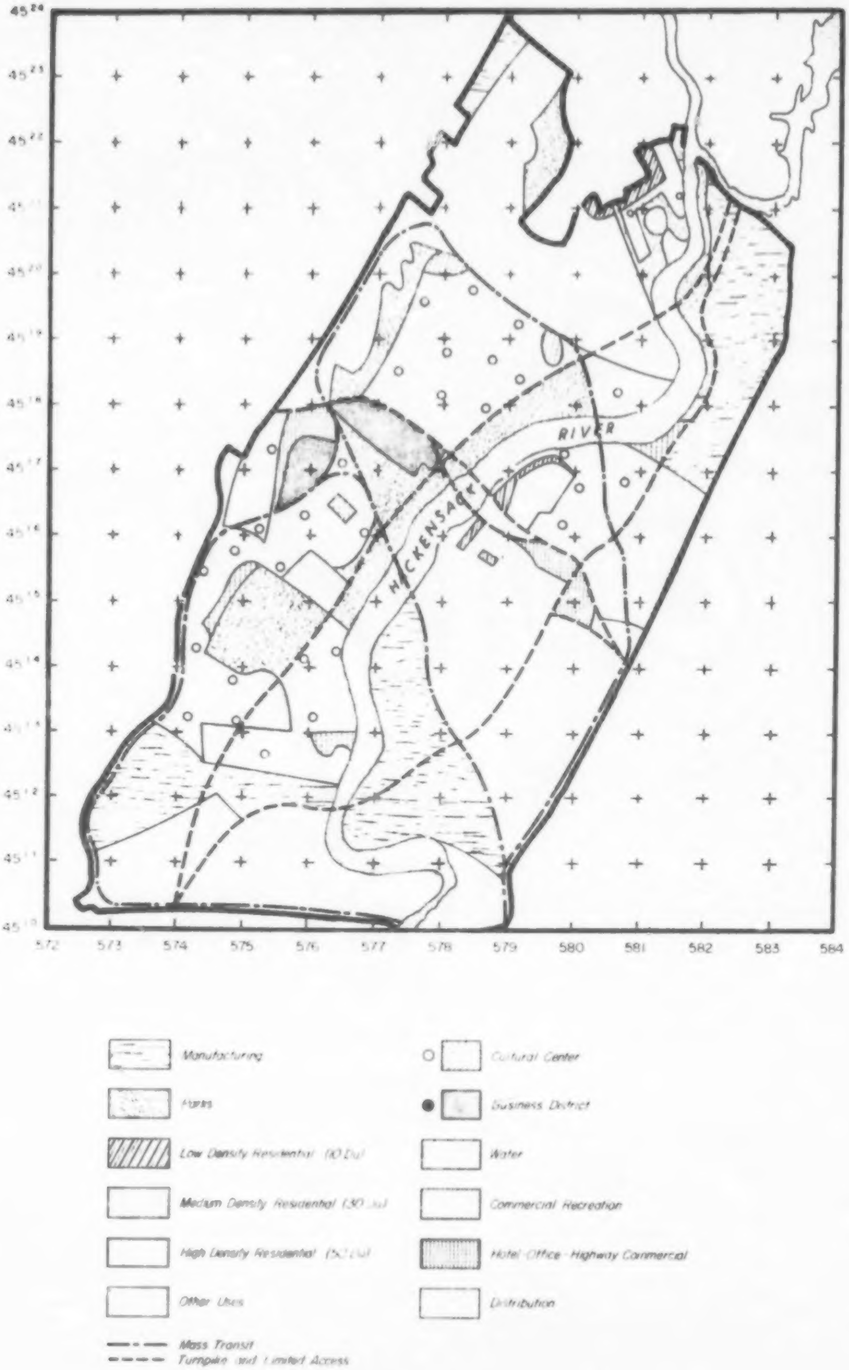
Medium Density Residential (20 Du)
High Density Residential (80 Du)
Special Uses
Cultural Center
Business District
Water
Commercial Recreation
Hotel-Office-Highway Commercial
Distribution
Turnpike and Limited Access

Figure 4 Alternative Meadowlands Land Use Plan No. 1A-Self-Supporting New Town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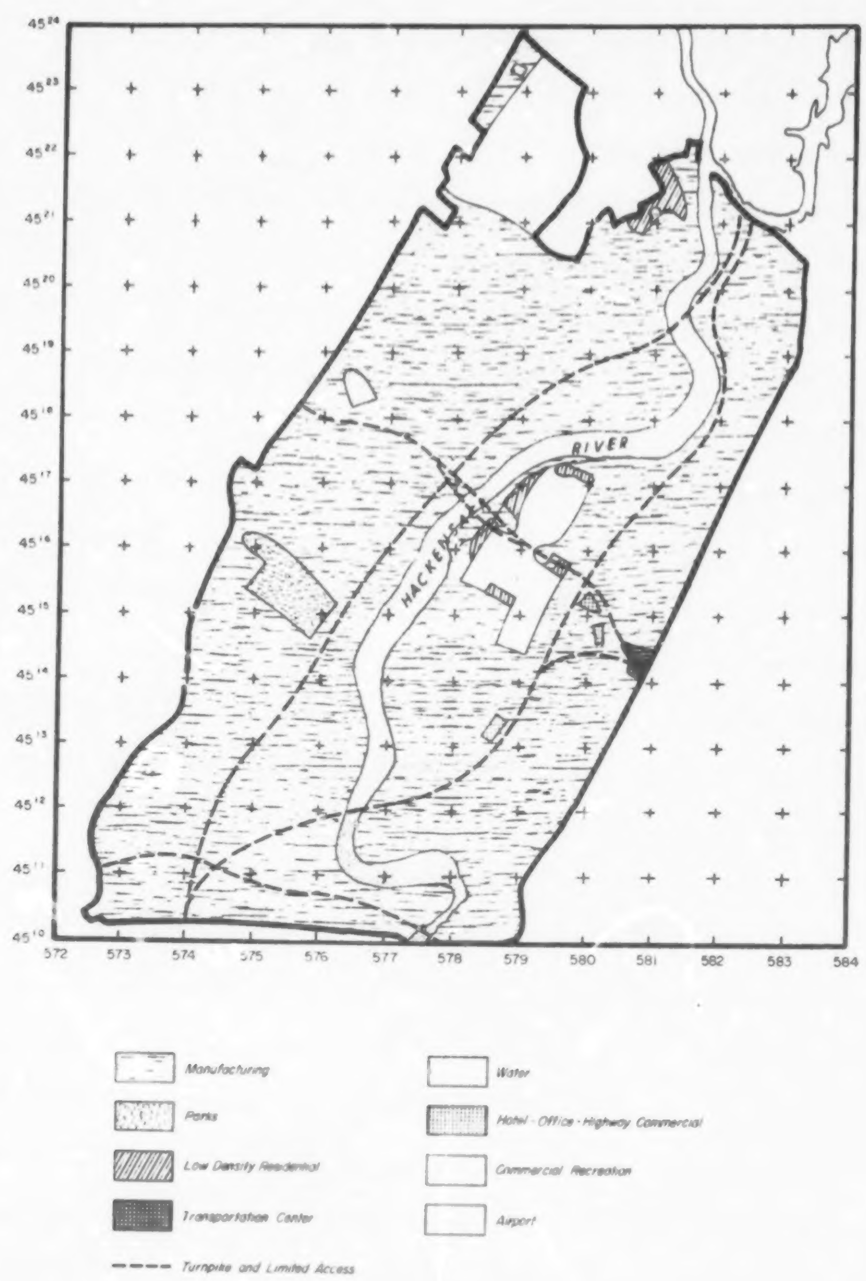
Parks
Low Density Residential (10 Du)
Medium Density Residential (30 Du)
High Density Residential (50 Du)
Other Uses
Cultural Center
Business District
Water
Commercial Recreation
Hotel-Office-Highway Commercial
Distribution
Mass Transit
Turnpike and Limited Access

Figure 5 Alternative Meadowlands Land Use Plan No. 1B-Expansion of New York City Urban Core



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HACKENSACK
RIVER
Manufacturing
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Low Density Residential
Transportation Center
Turnpike and Limited Access
Water
Hotel - Office - Highway Commercial
Commercial Recreation
Airport

Figure 6 Alternative Meadowlands Land Use Plan No. 1C-Trend Development Based on Current Zoning

The basic data and assumptions concerning the land uses for each of the plans were supplied by the HMDC and were processed and coded for input to the AQUIP System as described in the Task 1 Report. The resultant percent mix of land use categories, and population and traffic projections for the different plans are summarized in Table 3.

The four plans show significant differences both in the relative location of land uses and in the percent mix of land use categories. Plan 1, the Master Plan, is characterized by a large amount of open space (31% including open water), a relatively low population (148,000), and a broad mix of industrial and commercial activities. The dominant feature of the plan is the expansive area along the Hackensack River devoted to parks and conservation land. Only 6% of the total area is allocated to residential area, which consists mostly of high density island high-rise apartments and parkside residential areas located at points within this open space region. The business and commercial activities are located primarily in the central region of the Meadowlands west of the Hackensack River. Industrial activities (i.e., manufacturing, 8%, and distribution, 22%) are largely located in the eastern half of the region, although a sizable area (8%) devoted to research industry is located along the western border of the district. Plan 1 also includes various modes of public transportation, including novel means of waterborne transit, as well as new roadways. Arterials servicing the high density residential areas are located to minimize local surface street traffic.

In contrast, Plan 1A, the Self-Contained New Town, is characterized by a higher population (408,000), greater residential area (17%), and less open space (18%). The open space areas are predominantly located on the fringes of residential areas, acting as buffers to surrounding industrial areas.

TABLE 3

SUMMARY OF LAND USE INFORMATION FOR HACKENSACK MEADOWLANDS PLANS

Land Use Categories	Percent of Total Plan Area			
	Plan: 1	1A	1B	1C
Residential(1)				
10 DU/AC (dwelling units/acre)	1	2	1	1
20 DU/AC		7		
30 DU/AC			5	
50 DU/AC	5		15	
80 DU/AC		8		
TOTAL	6	17	21	1
Commercial & Industrial(1)				
Commercial	4	4	3	1
Manufacturing (light & heavy)	8	14	15	18
Research	8	0	0	0
Distribution	22	19	22	50
Special Use	1	0	0	0
Airport & Transportation Center	5	4	4	4
TOTAL	48	41	44	73
Open Space(1)				
Water	11	7	7	7
Parks & Conservation	20	11	11	2
TOTAL	31	18	18	9
Other(1)				
Highway & Railroad	12	21	15	14
Special	3	3	2	3
TOTAL	15	24	17	17
TOTAL LAND AREA (19,600 acres)	100%	100%	100%	100%
Total Population(2)	147,604	408,080	469,788	8,161
Total Students(2)	25,758	59,689	114,647	0
Total VMT/Year $(x10^{6})$ (3)	1,040	1,405	1,515	970

(1) As coded from land use maps -- figures used may not correspond exactly with original estimates given by the HMDC.

(2) As computed from land use data.

(3) Totals include the regional network traffic of $930x10^{6}$ VMT: in addition, $4x10^{6}$ hrs. idling/yr. are assumed for parking lots for all plans.

The primary commercial and industrial land use activities are devoted to manufacturing (14%) and distribution (19%). A significant feature of this plan is that essentially all of the population is located within the central portion of the planning region spread from west to east with low density areas in the west and extremely high density areas in the east. Furthermore, nearly all manufacturing activity is located in the southern portion of the planning region, while distribution activities are located in both the eastern portion of the region and in the vicinity of Teterboro airport. Characteristically, major access roadways are on the fringe of the residential areas to reduce surface street traffic. Since it is assumed that employment will be served mostly by local population, and that most of the journey to work trips will be served by the local roadway system, a significantly high percentage of land use is devoted to highways (21%). Moreover, no rapid transit is indicated in the plan. Consequently, the total miles of vehicular traffic projected for this plan (1.4 billion VMT/yr) reflects both the higher population and the increased levels of local traffic.

Plan 1B, the New York City Urban Core Expansion, is nearly identical to Plan 1A in percent mix of land use categories but has a significantly different location of these land use activities. The primary difference is that nearly all residential area (21%) is located in the western part of the district; and while Plan 1A has areas of low and extremely high density dwelling units, Plan 1B has mostly intermediate density dwelling units. The eastern portion of the Meadowlands is predominantly devoted to commercial and industrial land use activities. Manufacturing (15%) is widely dispersed, being located mostly in the southern and northeastern portions of the district. Distribution (22%) is similarly dispersed widely throughout the region. Again, as in Plan 1A, open space is used as a buffer between residential and industrial areas, and to expand the open space along the river. Plan 1B has the largest projected population (nearly 470,000) and the largest projected amount of traffic (over 1.5 billion VMT/year) of the four plans. Because of its planned close relationship to the New York City urban core, this plan also contains a substantial amount of rapid transit and commuter railroads, in addition to new arterials to serve the residential areas.

Plan 1C, the Trending of Current Zoning, is significantly different from the other three plans in the percent mix of land uses. It contains less than 1% residential area (to serve a projected population of approximately 8,000), while having little open space (9%) except for that associated with open water. Most of the region is devoted to commercial and industrial activities (73%), primarily distribution (50%). Industrial areas (18%) were allocated by the HMDC to 10-acre plots as shown in Figure 7. Furthermore, because of the low population, this plan also has the lowest projected traffic (0.97 billion VMT/year), reflecting primarily the regional network traffic.

6.3 Evaluation of Plans

6.3.1 Compliance with Ambient Air Quality Standards

One of the fundamental criteria for the assessment of air quality associated with each land use plan is based on compliance with ambient air quality standards (AAQS). In order to assess compliance with standards, however, the calculated annual average pollutant concentrations must be compared to corresponding annual average standards. As shown in Table 4, standards based on annual average concentrations do not exist for all pollutants, and such direct comparisons cannot be made. As a result, equivalent

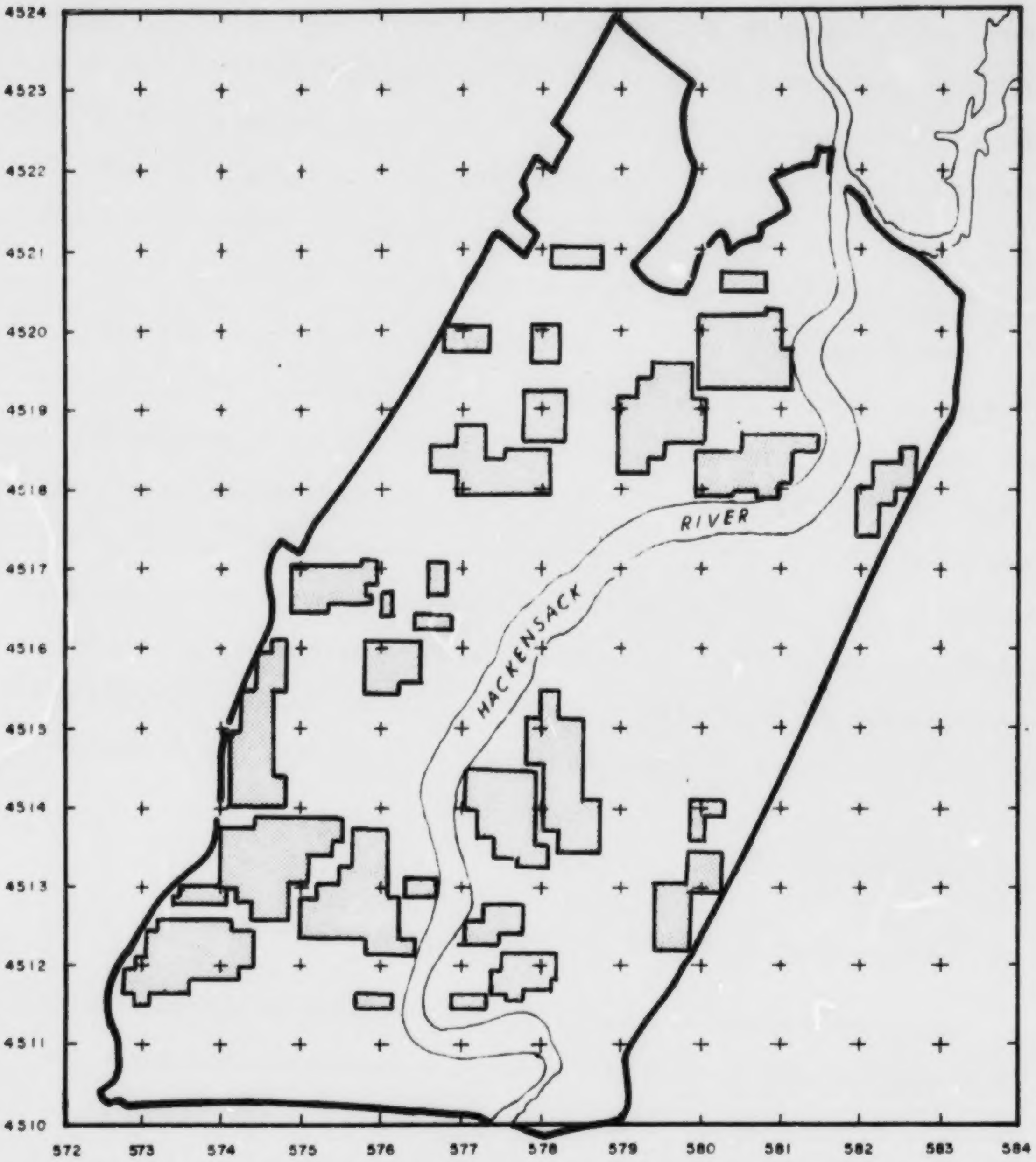
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Figure 7 Location of Manufacturing and Industrial Land Use Categories for Plan 1C

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TABLE 4

Federal Ambient Air Quality Standards Adopted by Environmental Protection Agency
April 30, 1971; New Jersey Ambient Air Quality Standards for Sulfur Dioxide and Particulates
$\mu g/m^3$ (ppm)[5]

Pollutant	1-hr max conc.[1]	3-hr max conc.[1] 6 am - 9 am	3-hr max conc.[1]	8-hr max conc.[1]	24-hr max conc[1]	Annual Average
Sulphur Oxides as SO_2						
Primary Federal Std.					365 (0.14)	80 (0.03)[2]
Secondary Federal Std.			1300 (0.5)[9]		260 (0.1)	60 (0.02)[2]
N.J. Std., (Chapt.13)	668 (0.25)[6]				267 (0.10)[6]	53 (0.02)[2]
" "	534 (0.20)[7]				214 (0.08)[8]	45 (0.017)[3]
Particulates						
Primary Federal Std.					260	75[3]
Secondary Federal Std.					150	60[3]
N.J.Std.,(Chapt.13)					195[6]	65[3]
Carbon Monoxide						
Primary & Secondary Fed.Std.	40,000 (35)			10,000 (9)		
Hydrocarbons as CH_4						
Primary & Secondary Fed.Std.		160 (0.24)[4]				
Photochemical Oxidants as O_3						
Primary & Secondary Fed.Std.	160 (0.08)					
Nitrogen Dioxide as NO_2						
Primary & Secondary Fed.Std.						100 (0.05)[2]

1 Maximum Values in Federal Standards are not to be exceeded more than once per year.
2 Arithmetic mean
3 Geometric mean
4 Nonmethane hydrocarbons, expressed as methane (CH_4), for the 3-hr period 6 am - 9 am.
5 Conversions from micrograms per cubic meter to parts per million are made at one atmosphere pressure and 25° C for Federal standards - 20° C C for New Jersey standards.
6 Arithmetic average concentration not to be exceeded and to be attained no more than once in twelve consecutive months.
7 Arithmetic average concentration to be attained or exceeded no more than nine times in twelve consecutive months.
8 Arithmetic average concentration to be attained or exceeded no more than four times in twelve consecutive months.
9 Any maximum three hour concentration not to be exceeded more than once per year.

Source: Environmental News Press Release, Friday, April 30, 1971; National Primary and Secondary Ambient Air Quality Standards
New Jersey Air Pollution Control Code, Chapter 13, Air Quality Standards

values of ambient air quality standards for annual time averaging periods were derived where both possible and meaningful. The resultant standards (or their extrapolated equivalents) as used in this analysis are summarized in Table 5, along with an indication of the method of derivation. As noted in Table 5, the standards used for comparison were the Federal secondary and New Jersey ambient air quality standards.

The primary basis for extrapolating values of standards from short period standards to equivalent annual average values was the Larsen model[28]. The one exception to this case, however, was for the hydrocarbon standard in which the Federal 3-hour air quality standard was used. The extrapolation of the 3-hour hydrocarbon standard to an annual average was not considered to be valid since background levels of hydrocarbons (less methane) from natural sources may be very high, possibly exceeding standards at various times and places. Thus, since background levels do not go to zero in the absence of man-made sources, it is not expected that the statistical model of Larsen, which is based on the reduction of empirical data associated with concentrations of pollutants which are due primarily to man-made sources, would apply directly. By contrast, it is expected that CO background levels are likely to approach zero in the absence of man-made sources; consequently, extrapolation of the short-term CO standard to an annual average would appear to be meaningful and valid.

The MARTIK program within the AQUIP System was used to project the 1990 mean annual pollutant concentrations at each grid point within the planning region. These data points were input to the LANTRAN program, which tabulated the ratio of the mean annual pollutant concentrations to their respective air quality standards at each grid point (a ratio designated as AQ/AAQS) and printed out a graphical display of such data for each grid cell within the

TABLE 5

EQUIVALENT ANNUAL AVERAGE AIR QUALITY STANDARDS

Pollutant	Standard(1)		Derivation
	($\mu g/m^3$)	(ppm)	
TSP	70.1	-- (3)	From N.J. (geometric mean) annual standard(2)
SO_2	53.0	0.02	N. J. annual standard
CO	1425.0	1.25	Extrapolation from Federal 8-hour standard using statistics from N.J. measurements data (2)
HC	160.0	0.24(3)	Federal (secondary) 3-hour standard(4)
NO_X	100.0	0.05(3)	Federal (secondary) annual standard

(1) Annual arithmetic mean, never to be exceeded

(2) Extrapolations based on use of Larsen Model. (Larsen, R.I. : "A Mathematical Model for Relating Air Quality Measurements to Air Quality Standards", Office of Air Programs Publication. No. AP-89, EPA, Office of Air Programs, Research Triangle Park, N.C., 1971.)

(3) Conversion to ppm not strictly possible without specifying composition of pollutant: HC is based on CH_4; NO_x is based on NO_2.

(4) Extrapolation of 3-hour (6 to 9 AM) standard to an annual standard not considered valid.

planning region. The maximum values of this AQ/AAQS ratio found for each pollutant within each plan are summarized in Table 6. The corresponding spatial patterns over each plan for each pollutant are shown in Figures 8 through 27. Hand-drawn isopleths for this AQ/AAQS ratio give a rapid indication of where air quality standards are exceeded within the Meadowlands region and by how much.

The analysis of total air quality concentrations within the Meadowlands planning region shows that the maximum predicted annual average concentrations for 1990 comply with ambient air quality standards for SO_2, CO, and NO_X. As indicated in Table 6, maximum SO_2 concentrations are on the order of 55 to 60% of the standard. Similarly, maximum CO concentrations are on the order of 70% of the standard (except for Plan 1B in which CO is approximately 90% of the standard), and maximum NO_X concentrations are on the order of 65% of the standard.

Calculations of the projected air quality for 1990 indicates that particulates (TSP) exceed standards in all four plans by a factor of approximately 2.5. Furthermore the analysis of background data shows that background TSP concentrations within the Meadowlands region (i.e., concentrations from sources other than the plans themselves), exceed air quality standards for 1990 in all four plans. The TSP emissions data shows that these high background concentration levels result primarily from the fact that particulates are predominantly related to fuel burning for space heating and that major control regulations are already in effect. As a result, little change is anticipated in current emissions factors for 1990.

The results also show that hydrocarbons exceed the air quality standards for all plans in 1990 by a factor of approximately 12. Furthermore as indicated in Table 6, the background concentration levels, which represent nearly

TABLE 6

SUMMARY OF PROJECTED 1990 AIR QUALITY DATA FOR THE MEADOWLANDS

Pollutant	Plan	Ratio of Total AQ to Annual AQ Standard		Background AQ as % of Total AQ	
		Minimum	Maximum	Minimum	Maximum
TSP	1	1.51	2.46	95	97
	1A	1.55	2.44	86	92
	1B	1.53	2.56	95	99
	1C	1.62	2.52	77	89
SO_2	1	0.34	0.55	85	95
	1A	0.37	0.58	75	88
	1B	0.35	0.56	78	88
	1C	0.40	0.61	64	96
CO	1	0.54	0.67	95	99
	1A	0.56	0.69	90	94
	1B	0.56	0.91	87	95
	1C	0.54	0.66	95	99
HC	1	8.65	12.3		99
	1A	8.69	12.3		99
	1B	8.78	12.3		99
	1C	8.73	12.3		99
NO_X	1	0.42	0.64	94	98
	1A	0.43	0.64	86	98
	1B	0.42	0.64	90	98
	1C	0.44	0.65	78	90

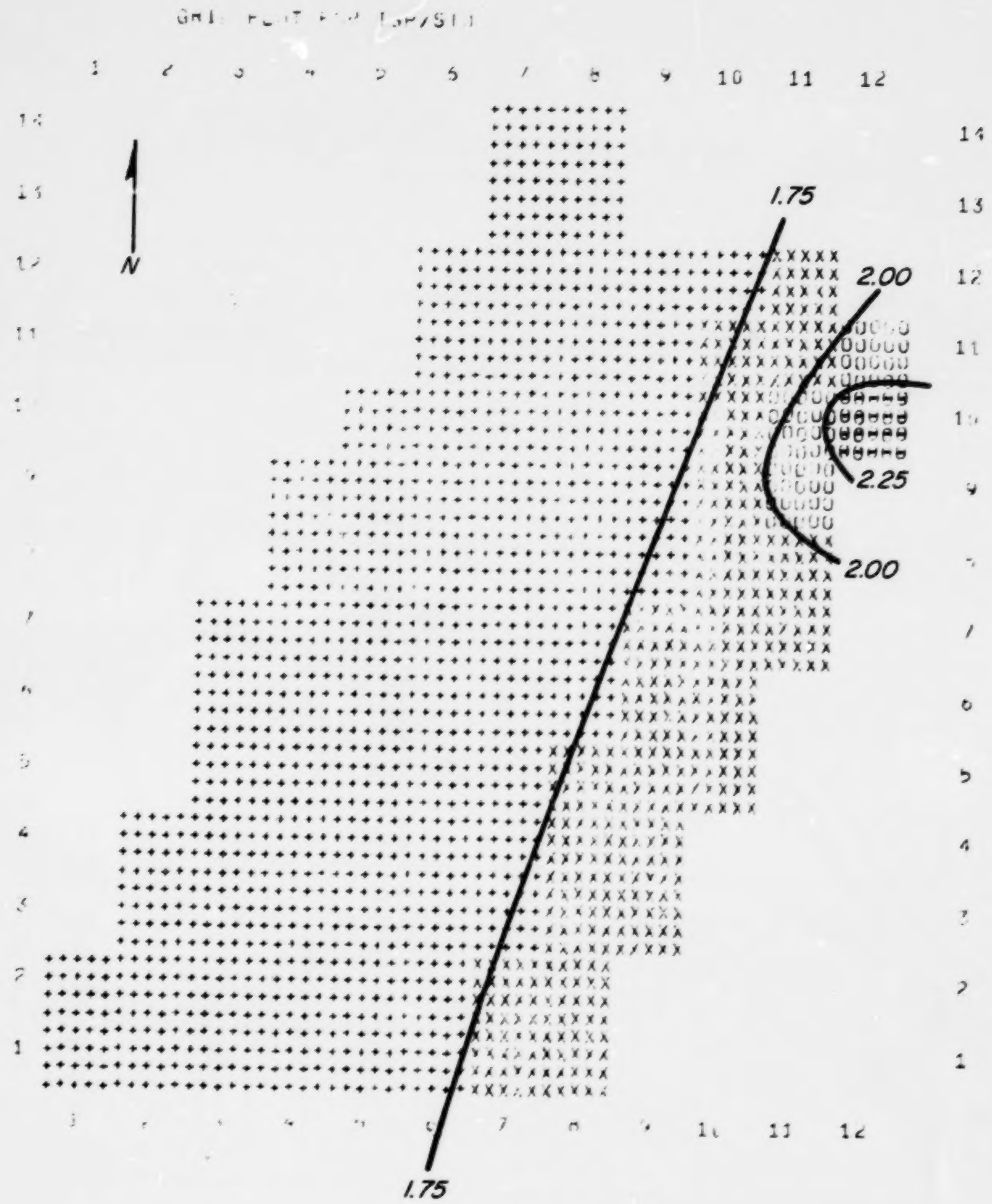
GRID PLOT FOR TSP/STD
1 2 3 4 5 6 7 8 9 10 11 12
14 13 12 11 10 9 8 7 6 5 4 3 2 1
N
1.75
2.00
2.25
2.00
1.75

Figure 8 Air Quality Contours for Particulates for Plan 1, Expressed as the Ratio of Air Quality/Air Quality Standard

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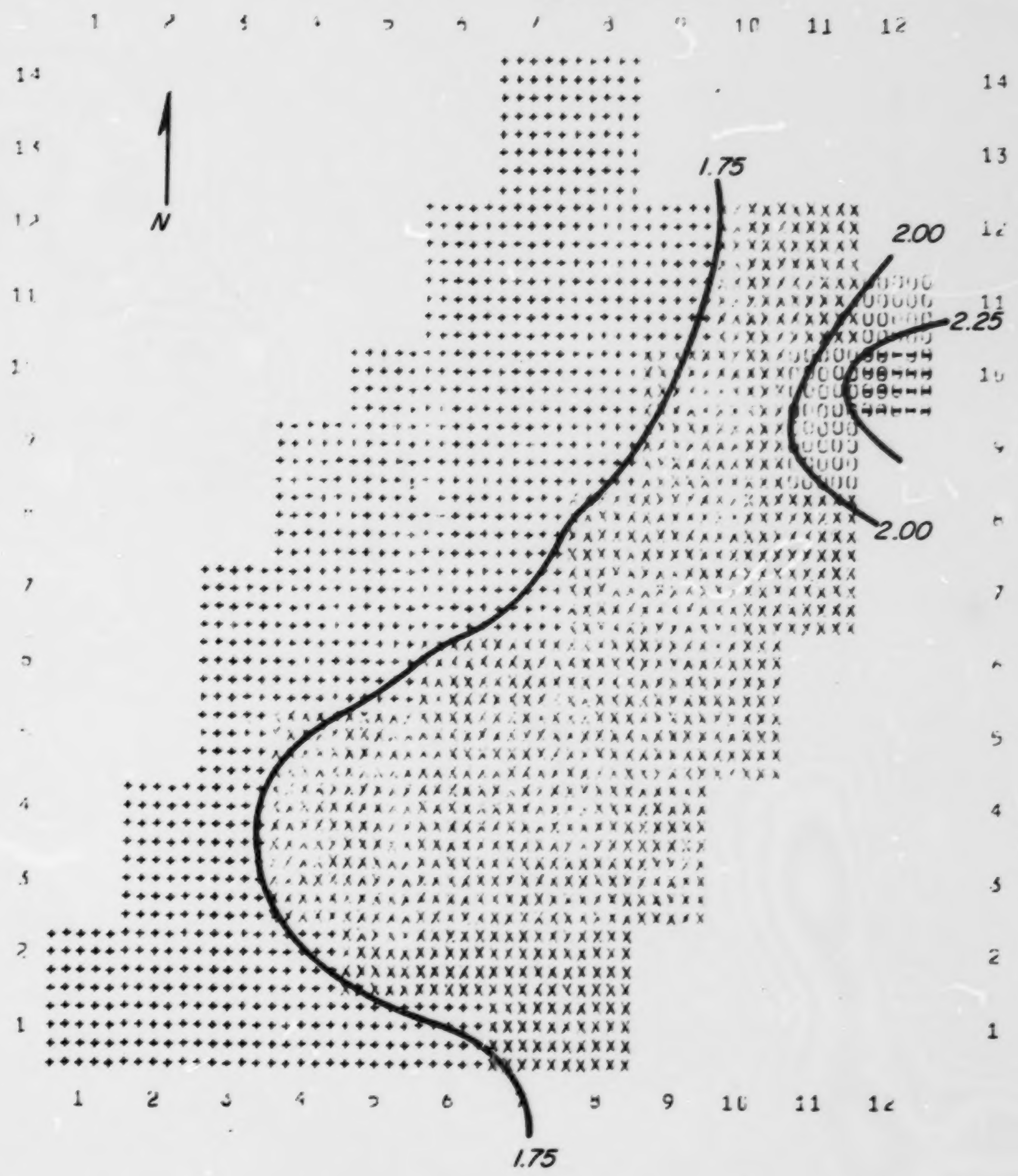

1.75
2.00
2.25
2.00
1.75
N
1
2
3
4
5
6
7
8
9
10
11
12
13
14

6427

Figure 9 Air Quality Contours for Particulates for Plan 1A, Expressed as the Ratio of Air Quality/Air Quality Standard

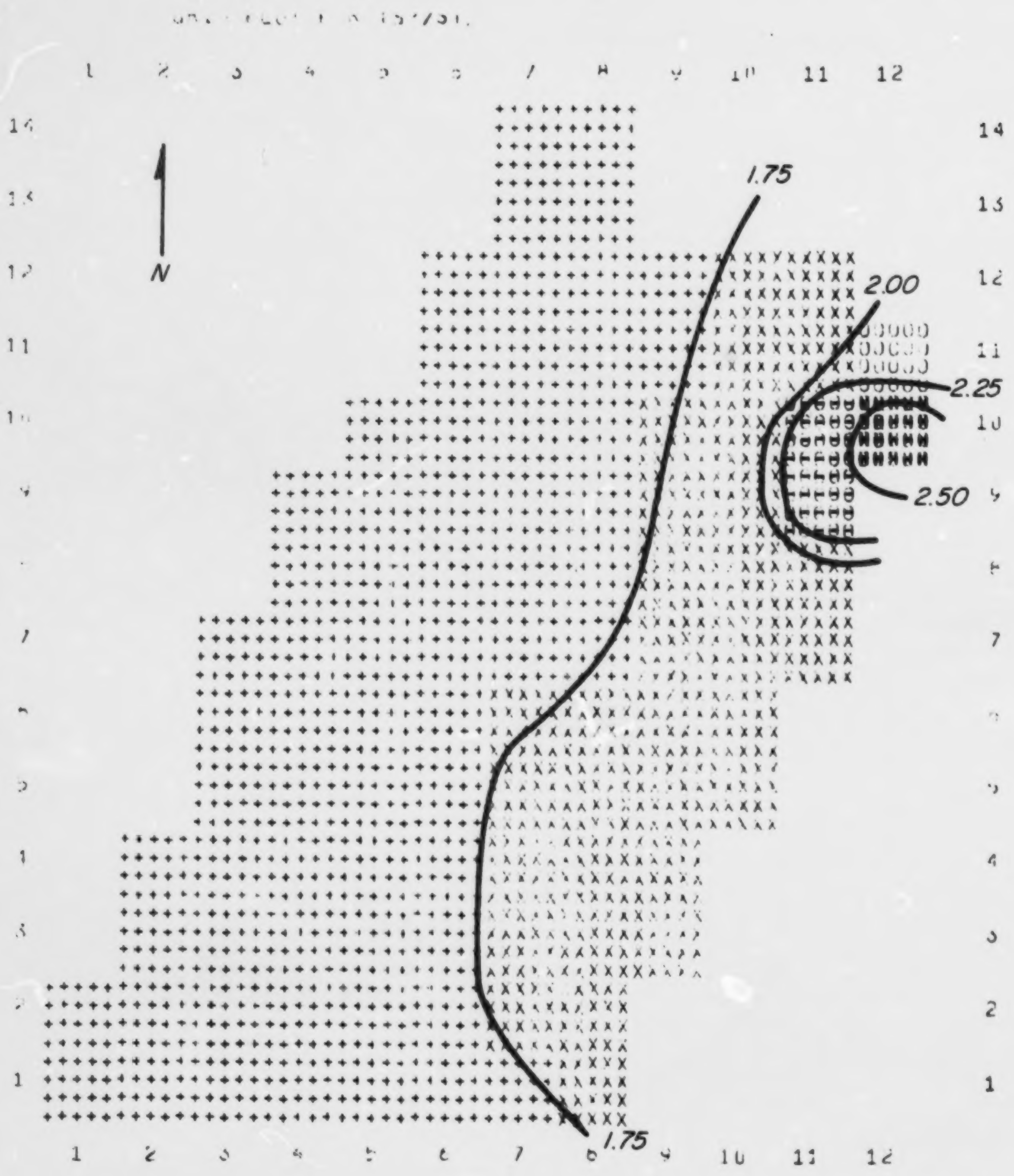

1 2 3 4 5 6 7 8 9 10 11 12
14
13
12
11
10
9
8
7
6
5
4
3
2
1
N
1.75
2.00
2.25
2.50
1.75

Figure 10 Air Quality Contours for Particulates for Plan 1B, Expressed as the Ratio of Air Quality/Air Quality Standard

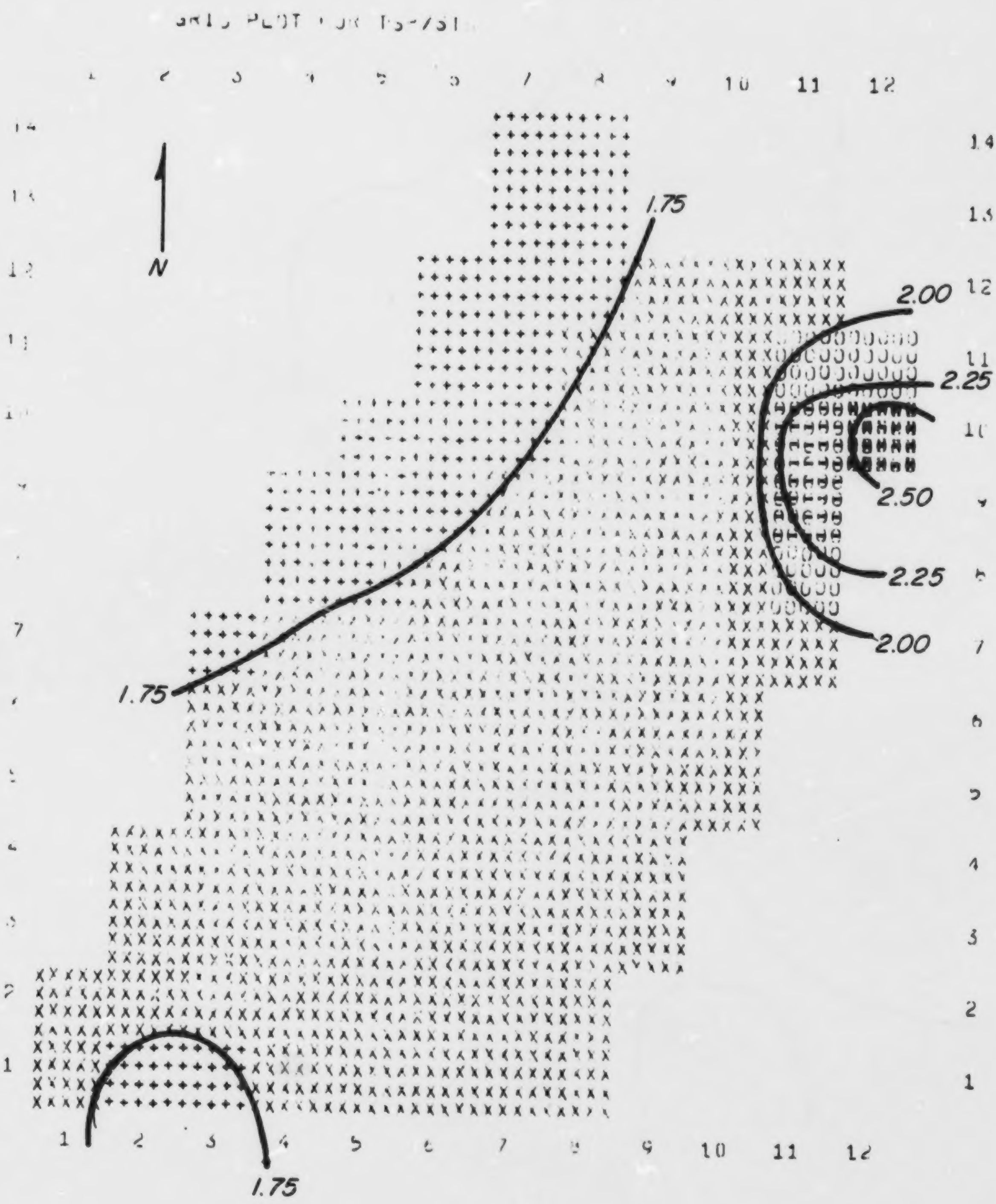


Figure 11 Air Quality Contours for Particulates for Plan 1C, Expressed as the Ratio of Air Quality/Air Quality Standard

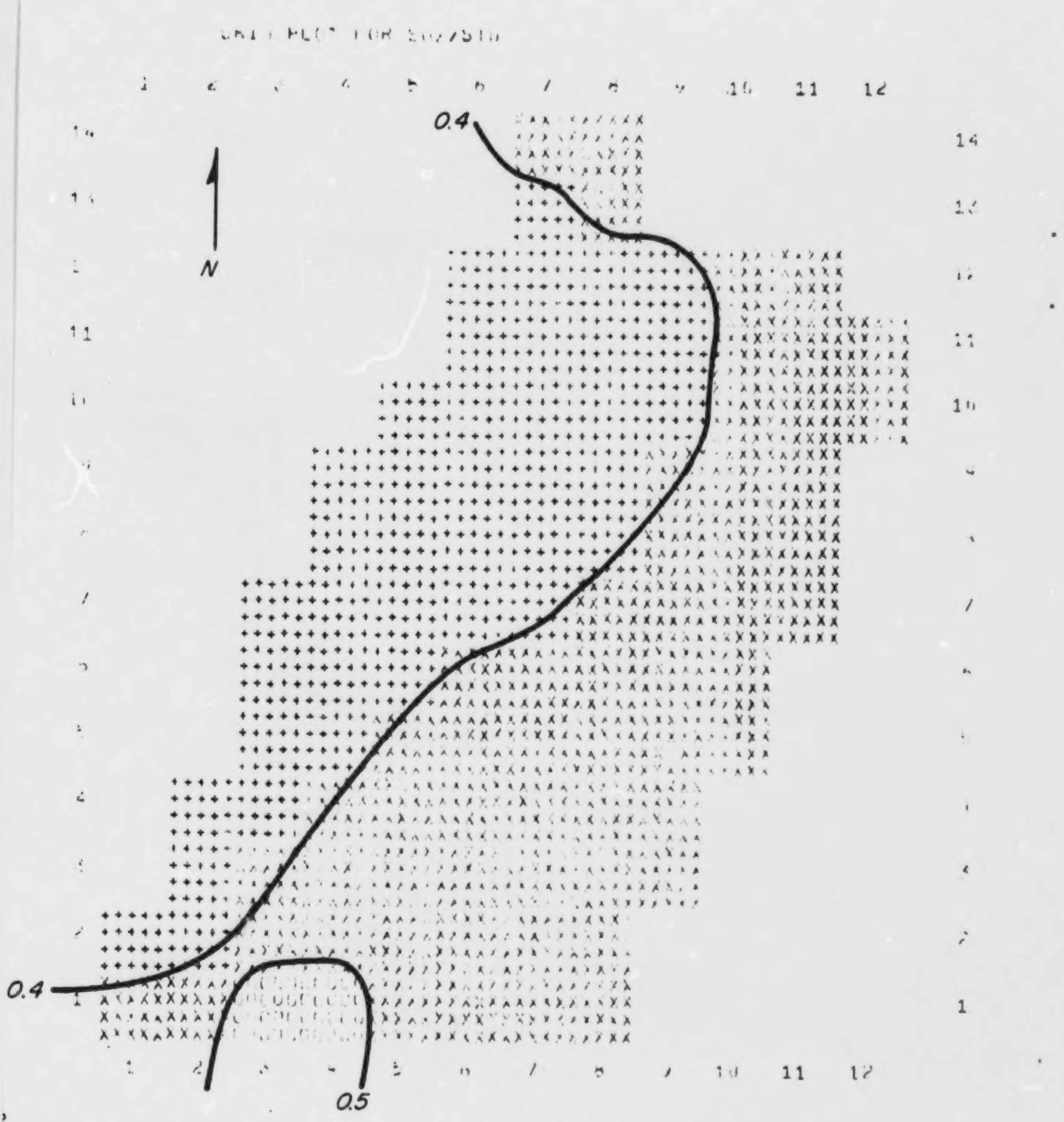

GRID PLOT FOR SO2/STD
1
2
3
4
5
6
7
8
9
10
11
12
14
13
12
11
10
9
8
7
6
5
4
3
2
1
N
0.4
0.4
0.5

Figure 12 Air Quality Contours for Sulfur Oxides for Plan 1, Expressed as the Ratio of Air Quality/Air Quality Standard

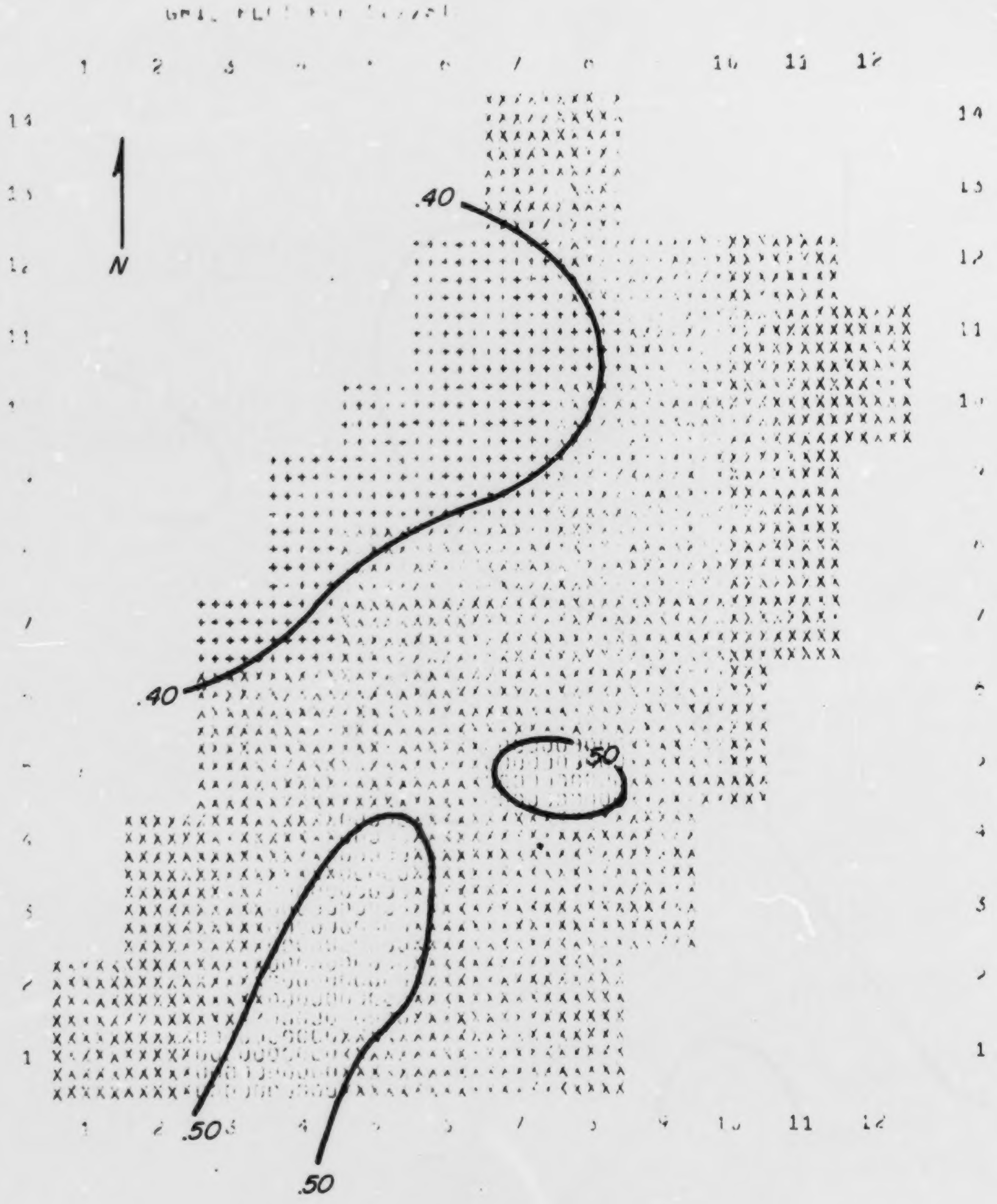

N
.40
.40
.50
.50
.50
1
1
11
11
12
12
14
14
1
1
3
3
5
4

Figure 13 Air Quality Contours for Sulfur Oxides for Plan 1A, Expressed as the Ratio of Air Quality/Air Quality Standard

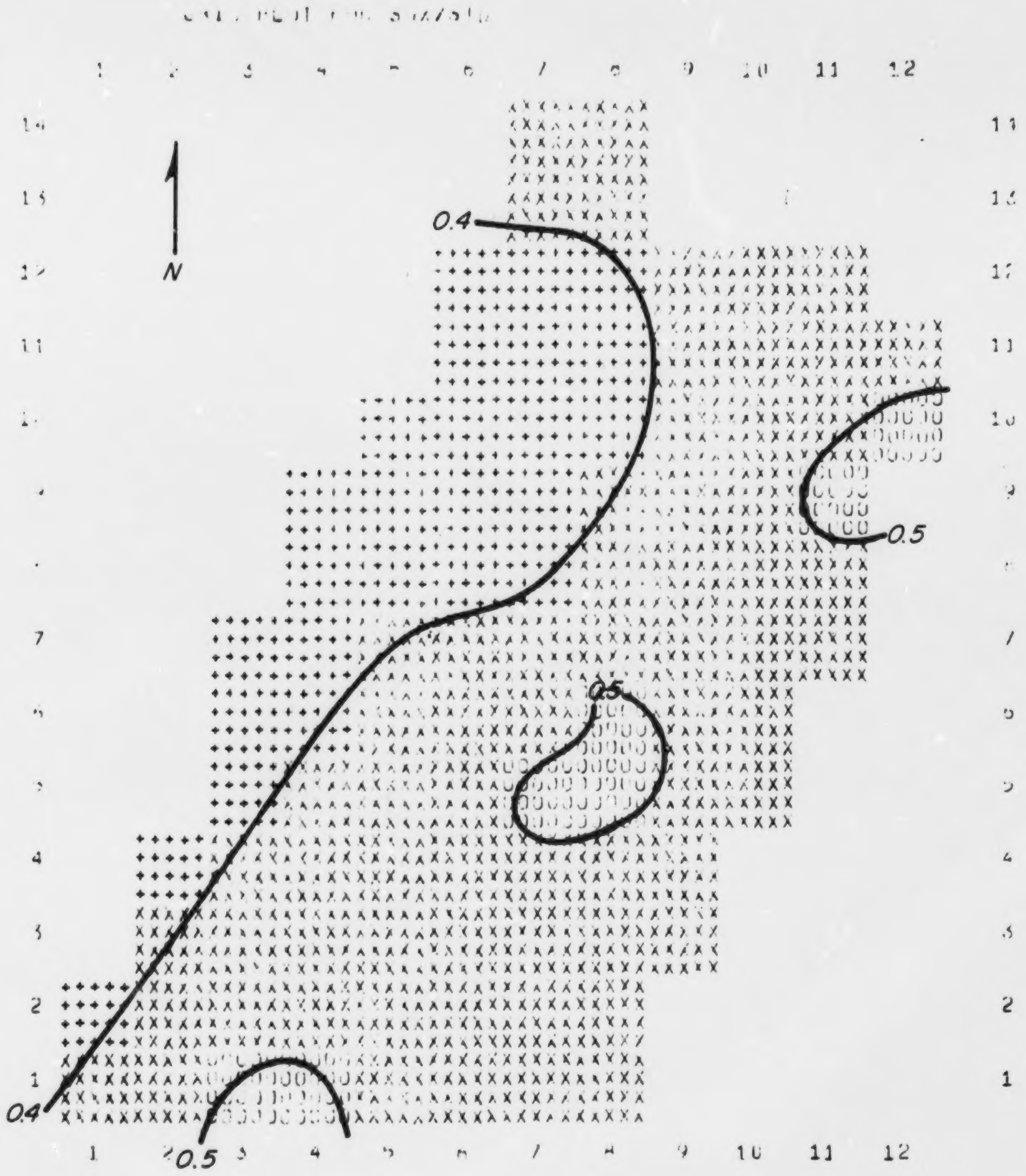

N
0.4
0.4
0.5
0.5
0.5
1
2
3
4
5
6
7
8
9
10
11
12

Figure 14 Air Quality Contours for Sulfur Oxides for Plan 1B, Expressed as the Ratio of Air Quality/Air Quality Standard

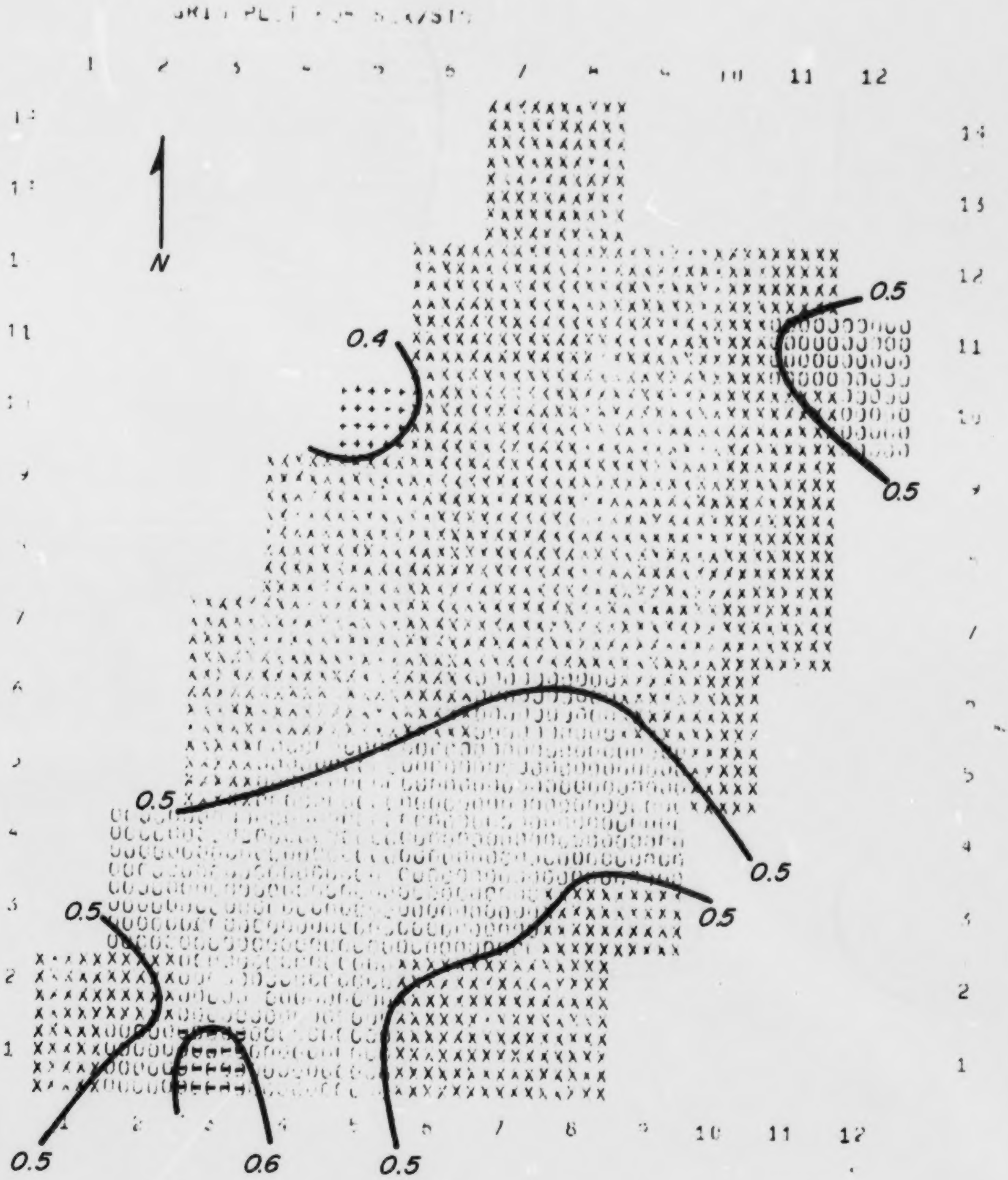

GRID PLOT FOR SOX/STD
1
2
3
4
5
6
7
8
9
10
11
12
N
0.5
0.4
0.5
0.5
0.5
0.5
0.5
0.5
0.5
0.6
0.5

Figure 15 Air Quality Contours for Sulfur Oxides for Plan 1C, Expressed as the Ratio of Air Quality/Air Quality Standard

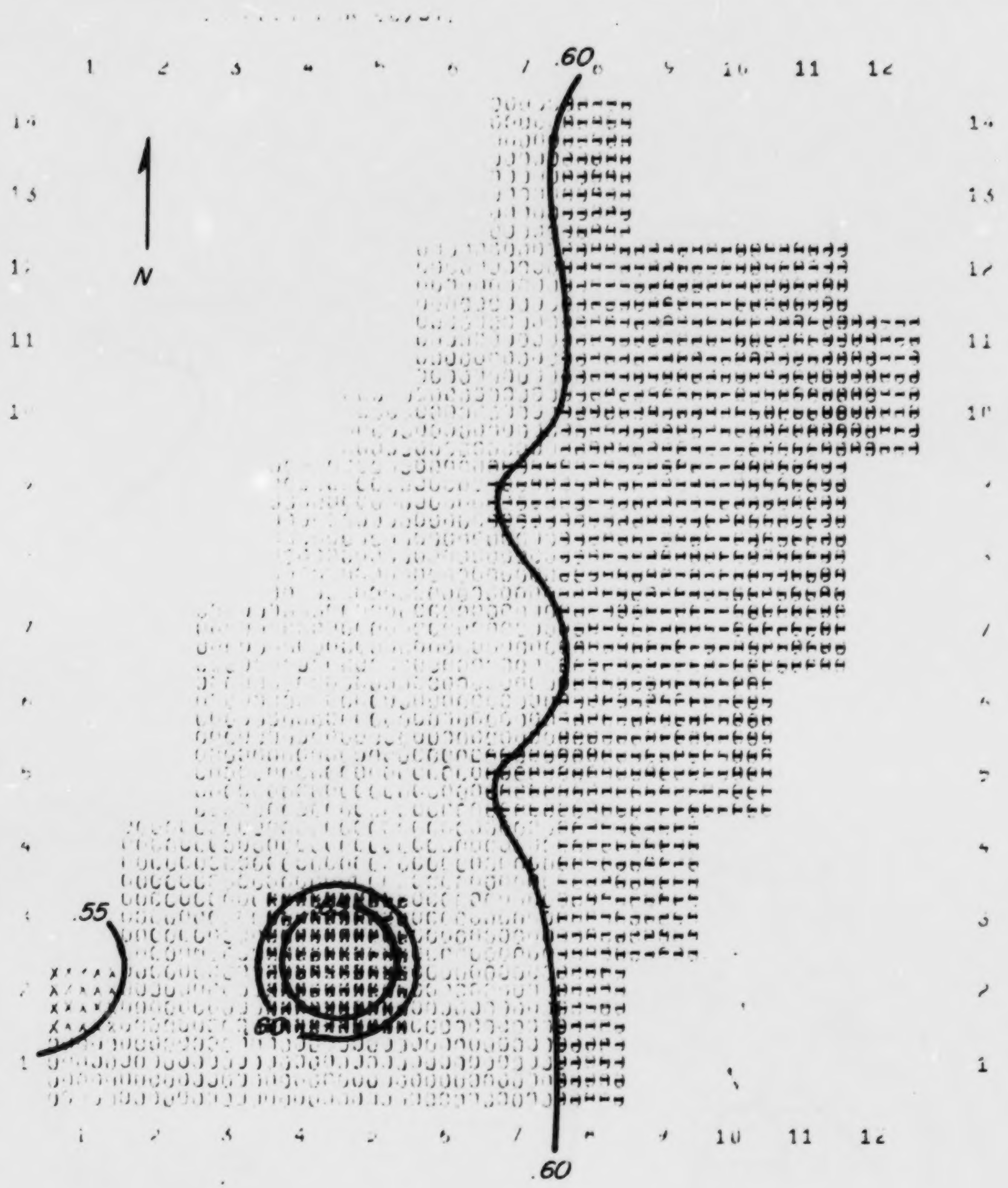
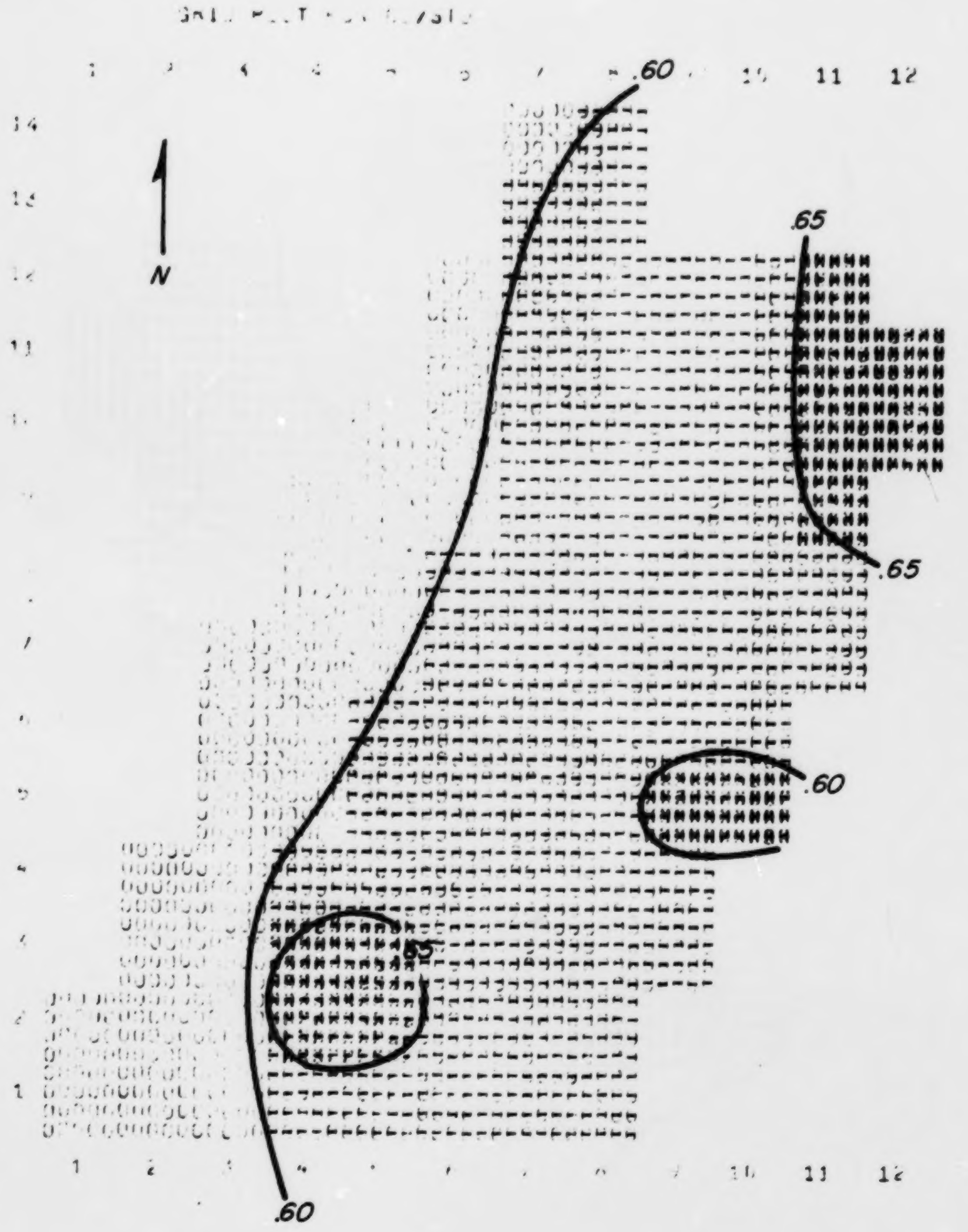

N
.60
.60
.55
.60
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Figure 16 Air Quality Contours for Carbon Monoxide for Plan 1, Expressed as the Ratio of Air Quality/Air Quality Standard



N
.60
.65
.65
.60
.65
.60
1 2 3 4 5 6 7 8 9 10 11 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14

Figure 17 Air Quality Contours for Carbon Monoxide for Plan 1A, Expressed as the Ratio of Air Quality/Air Quality Standard

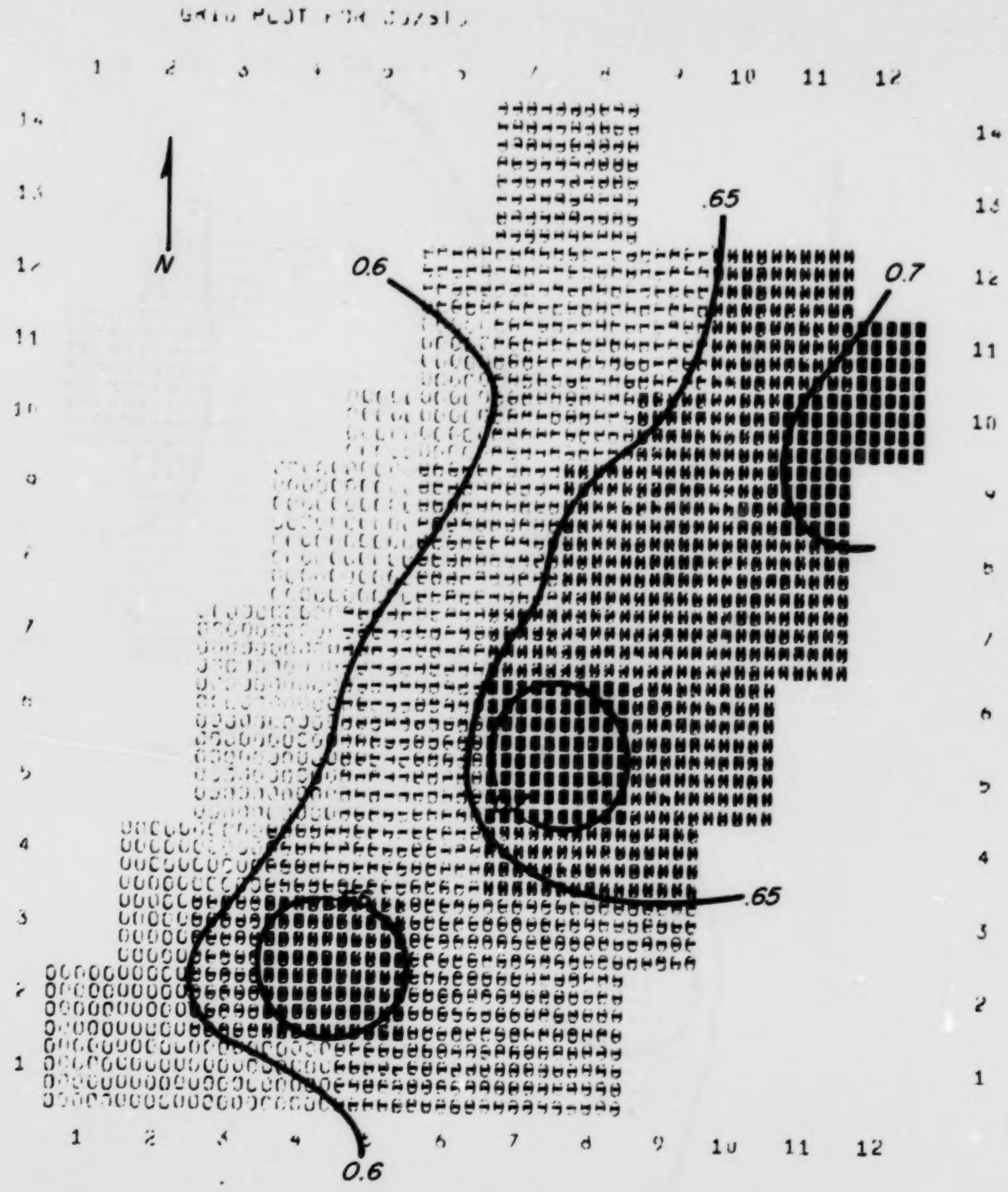

N
0.6
.65
0.7
.65
0.6
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Figure 18 Air Quality Contours for Carbon Monoxide for Plan 1B, Expressed as the Ratio of Air Quality/Air Quality Standard

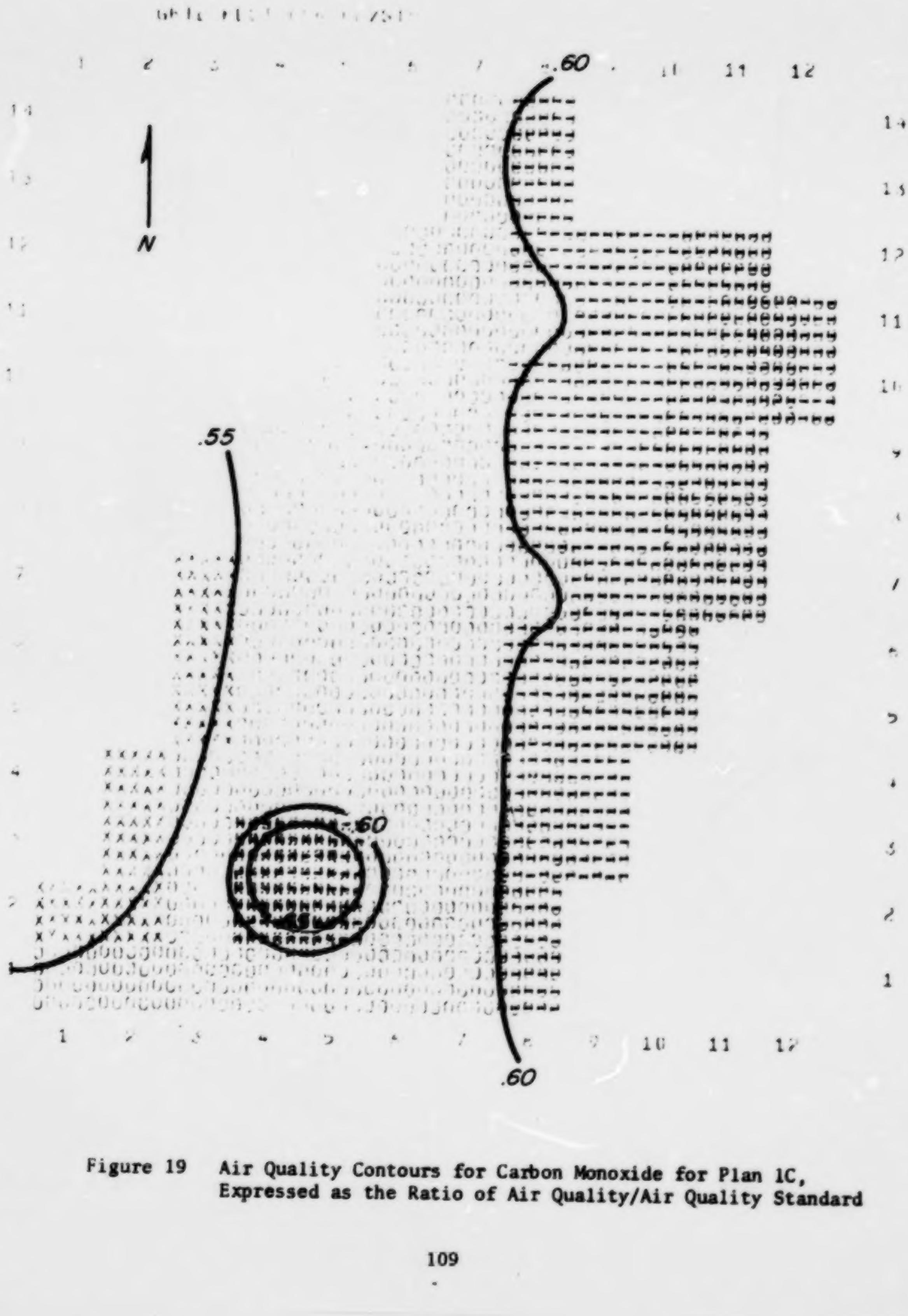

N
.60
.55
.60
.60
1
2
3
4
5
6
7
8
9
10
11
12
13
14

Figure 19 Air Quality Contours for Carbon Monoxide for Plan 1C, Expressed as the Ratio of Air Quality/Air Quality Standard

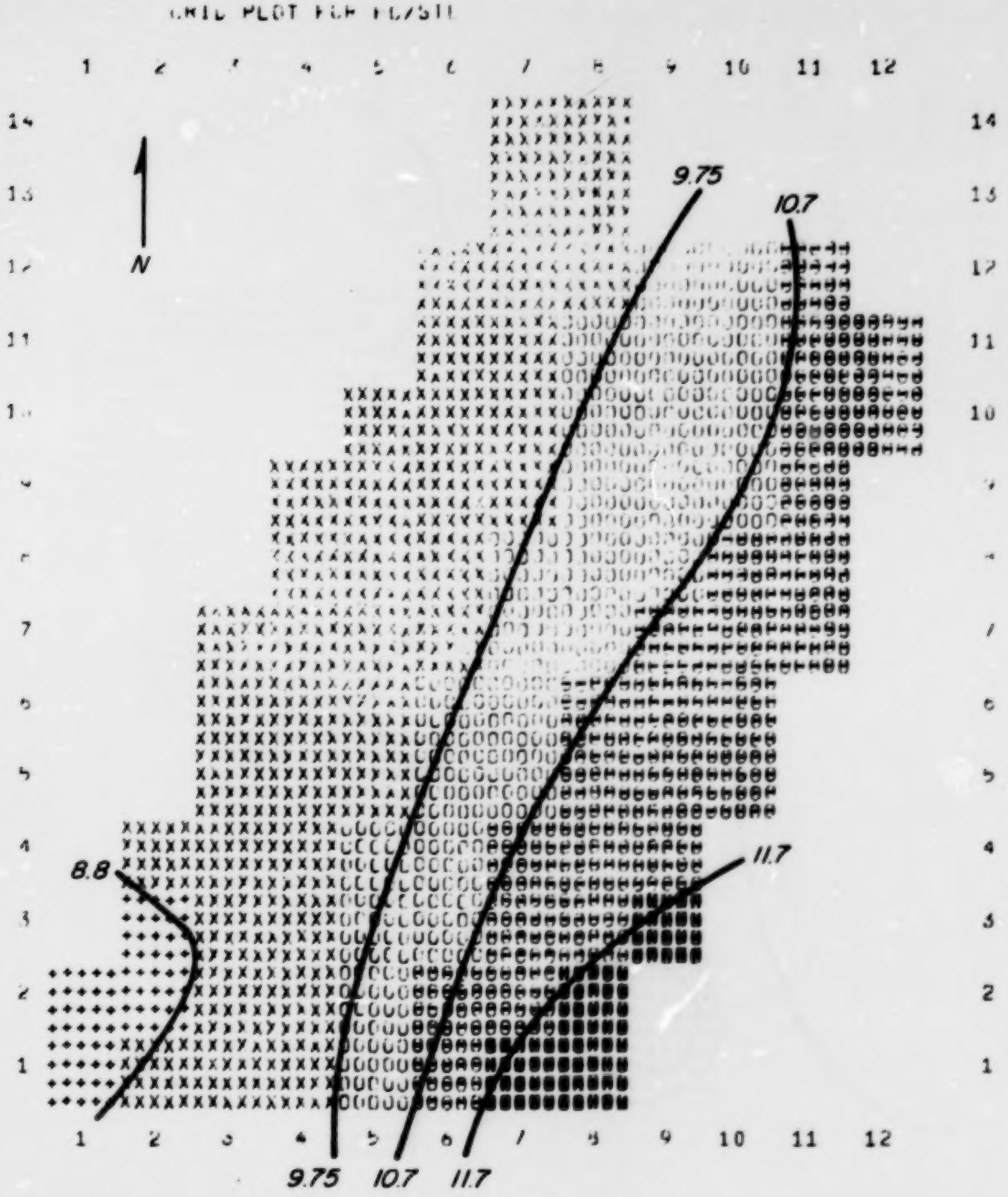

GRID PLOT FOR HC/STD
1 2 3 4 5 6 7 8 9 10 11 12
14 13 12 11 10 9 8 7 6 5 4 3 2 1
N
9.75
10.7
11.7
8.8
9.75
10.7
11.7

Figure 20 Air Quality Contours for Hydrocarbons for Plan 1, Expressed as the Ratio of Air Quality/Air Quality Standard

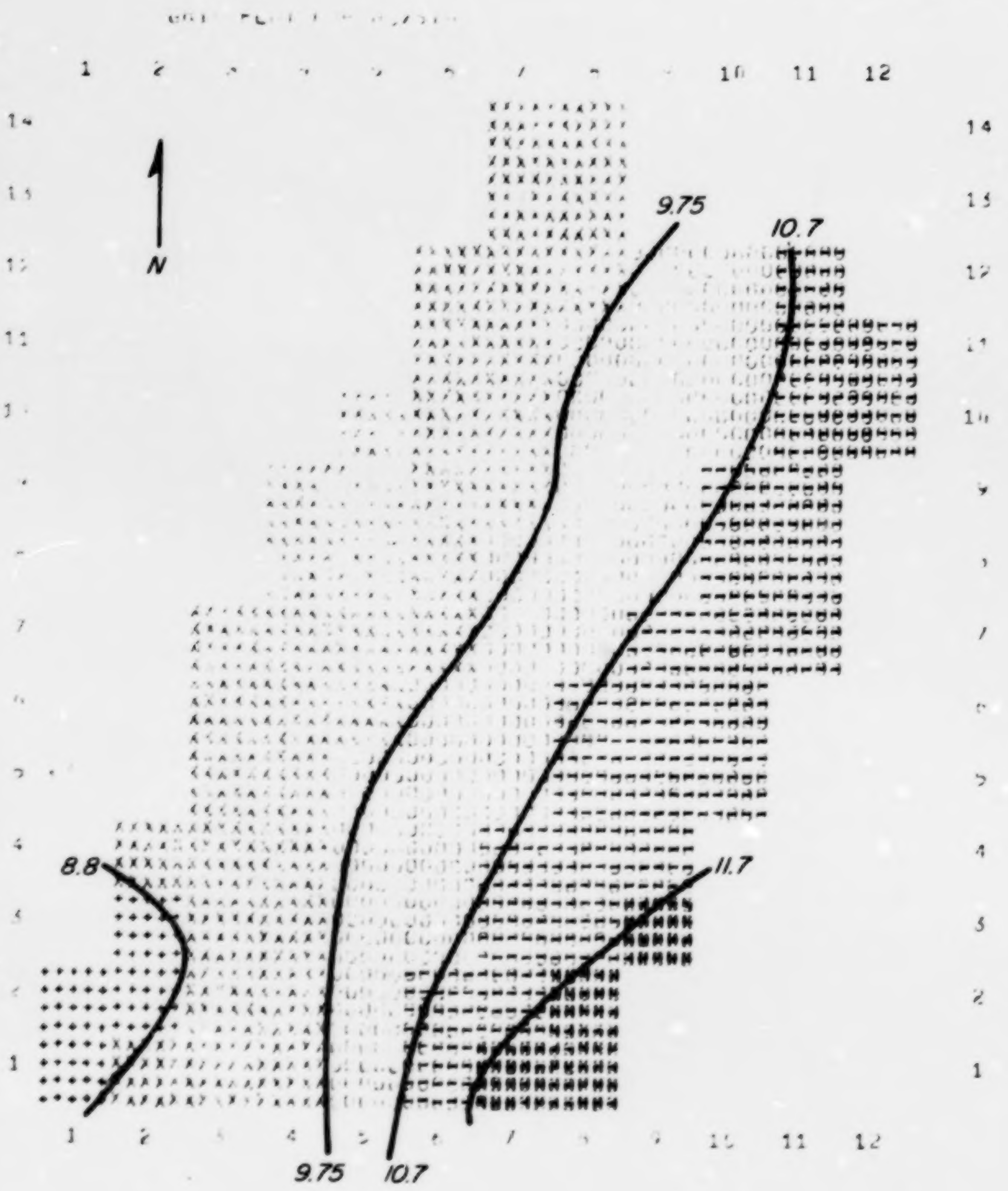

1
2
10
11
12
14
13
12
11
10
9
8
7
6
5
4
3
2
1
N
9.75
10.7
8.8
11.7
9.75
10.7

Figure 21 Air Quality Contours for Hydrocarbons for Plan 1A, Expressed as the Ratio of Air Quality/Air Quality Standard

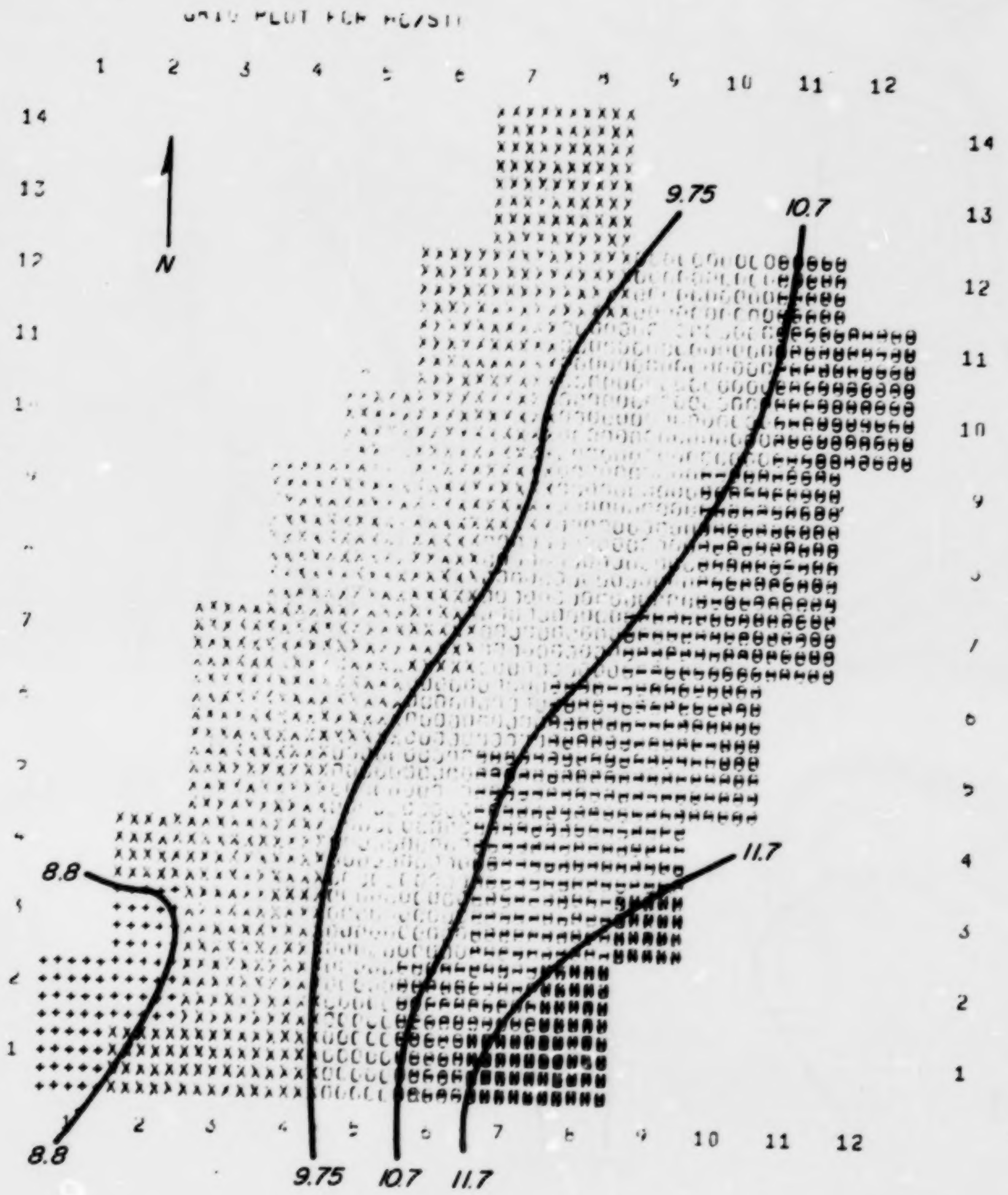

GRID PLOT FOR HC/STD
N
1 2 3 4 5 6 7 8 9 10 11 12
1 2 3 4 5 6 7 8 9 10 11 12 13 14
8.8
8.8
9.75
9.75
10.7
10.7
11.7
11.7

Figure 22 Air Quality Contours for Hydrocarbons for Plan 1B, Expressed as the Ratio of Air Quality/Air Quality Standard

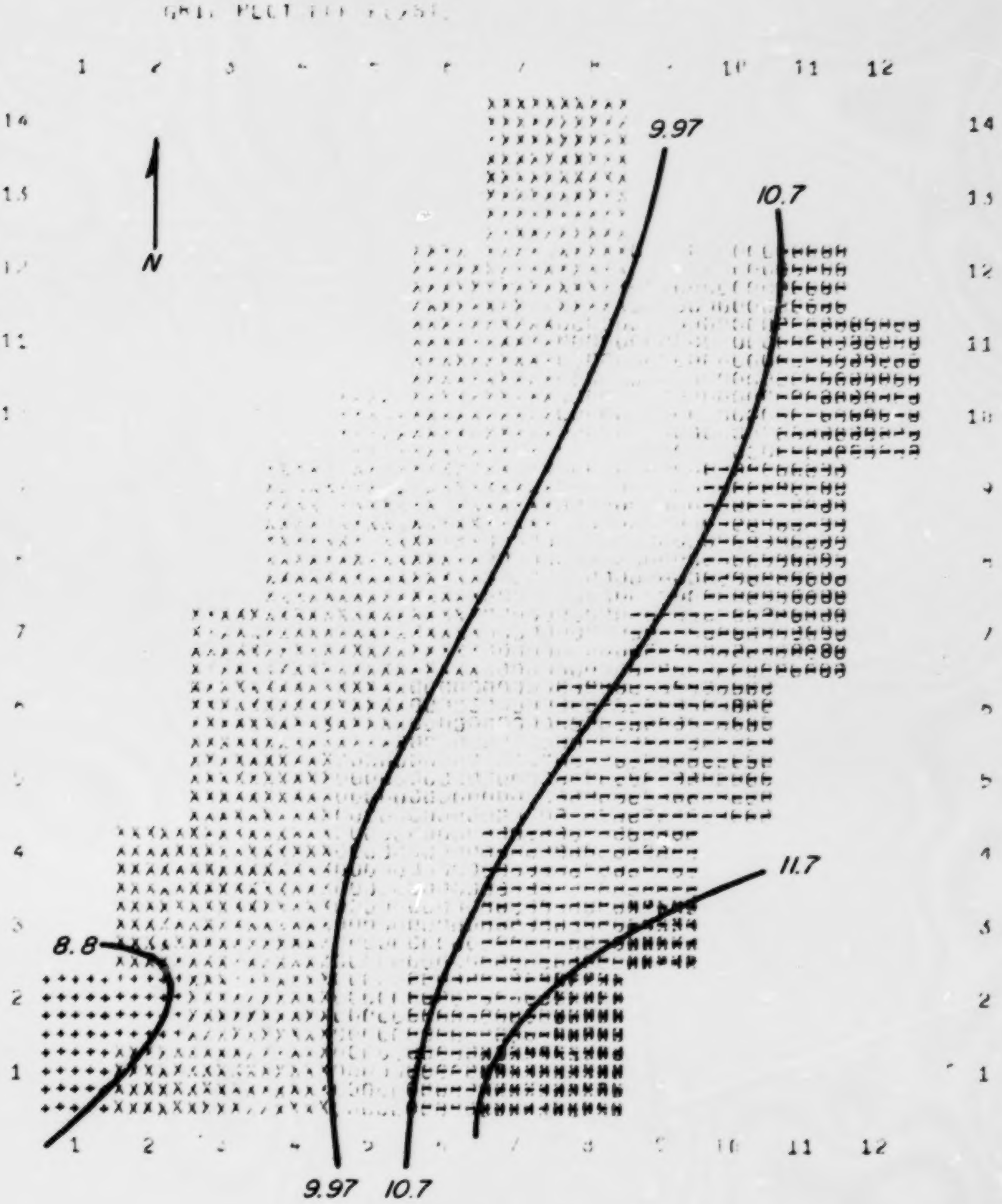

1 2 3 4 5 6 7 8 9 10 11 12
14
13
12
11
10
9
8
7
6
5
4
3
2
1
N
9.97
10.7
11.7
8.8
9.97
10.7

Figure 23 Air Quality Contours for Hydrocarbons for Plan IC, Expressed as the Ratio of Air Quality/Air Quality Standard

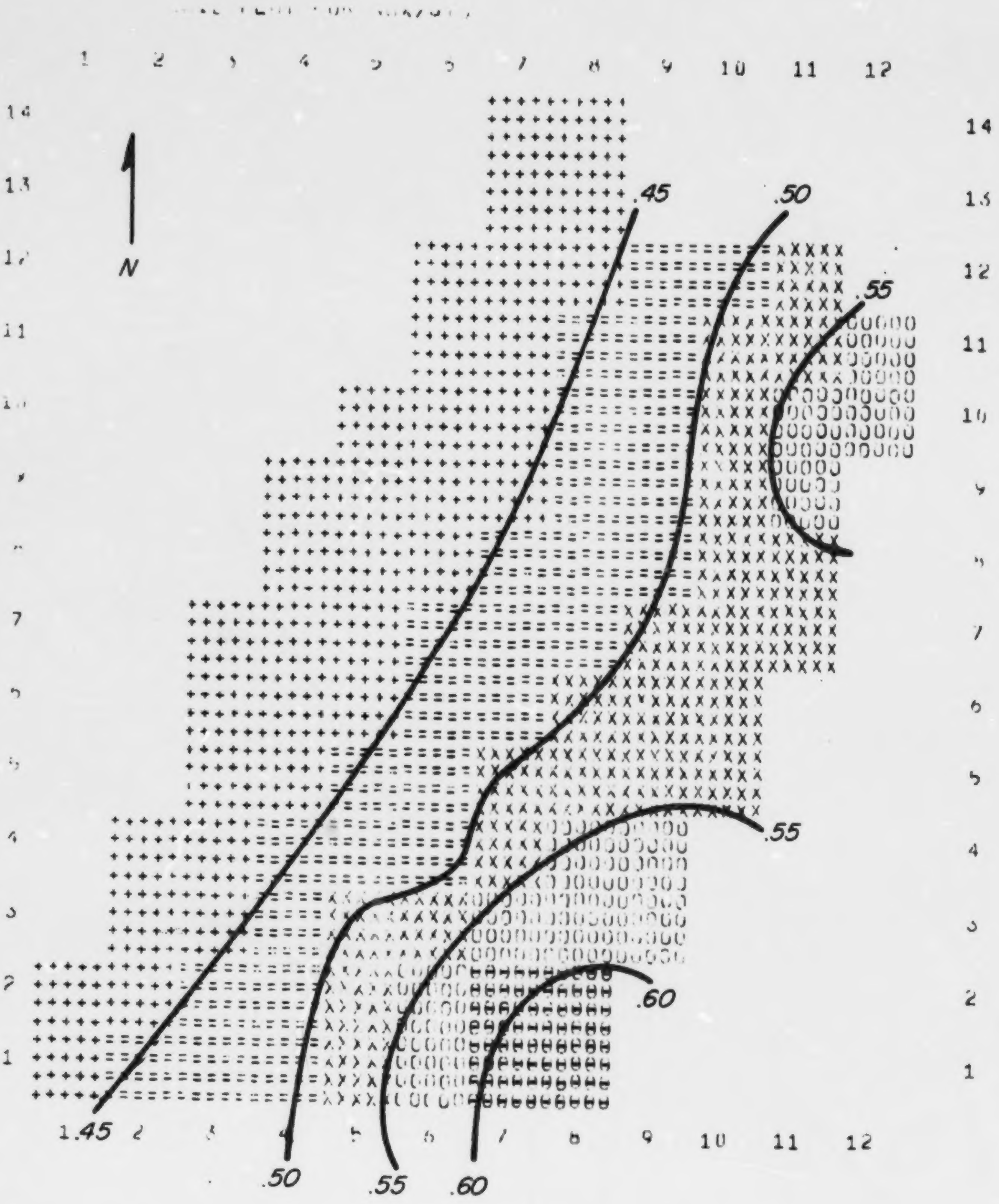

1 2 3 4 5 6 7 8 9 10 11 12
14 13 12 11 10 9 8 7 6 5 4 3 2 1
N
.45
.50
.55
.55
.55
.60
.60
1.45
.50
.55
.60

Figure 24 Air Quality Contours for Nitrogen Oxides for Plan 1, Expressed as the Ratio of Air Quality/Air Quality Standard

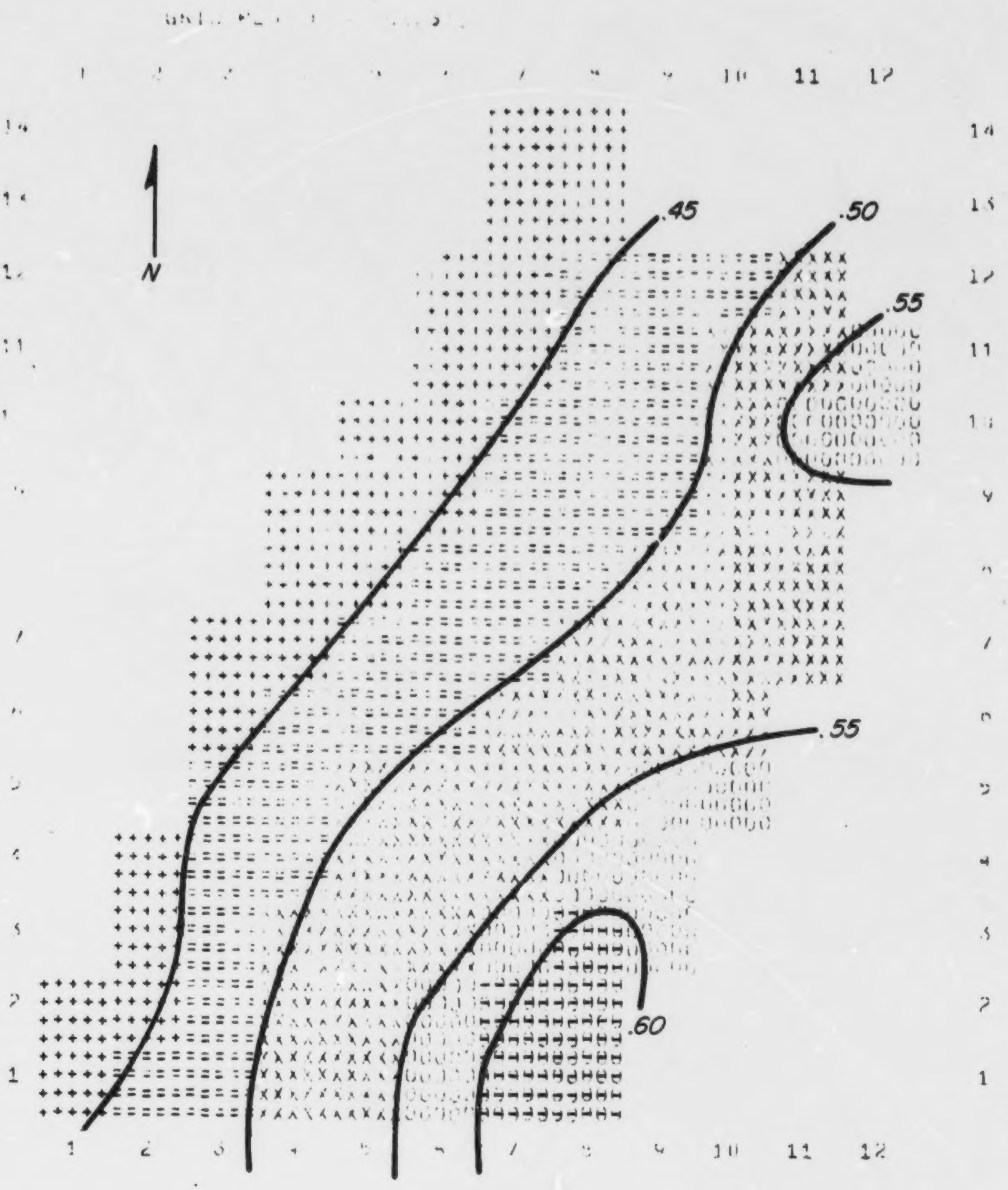

N
.45
.50
.55
.55
.60
1
2
3
4
5
6
7
8
9
10
11
12
6443

Figure 25 Air Quality Contours for Nitrogen Oxides for Plan 1A, Expressed as the Ratio of Air Quality/Air Quality Standard

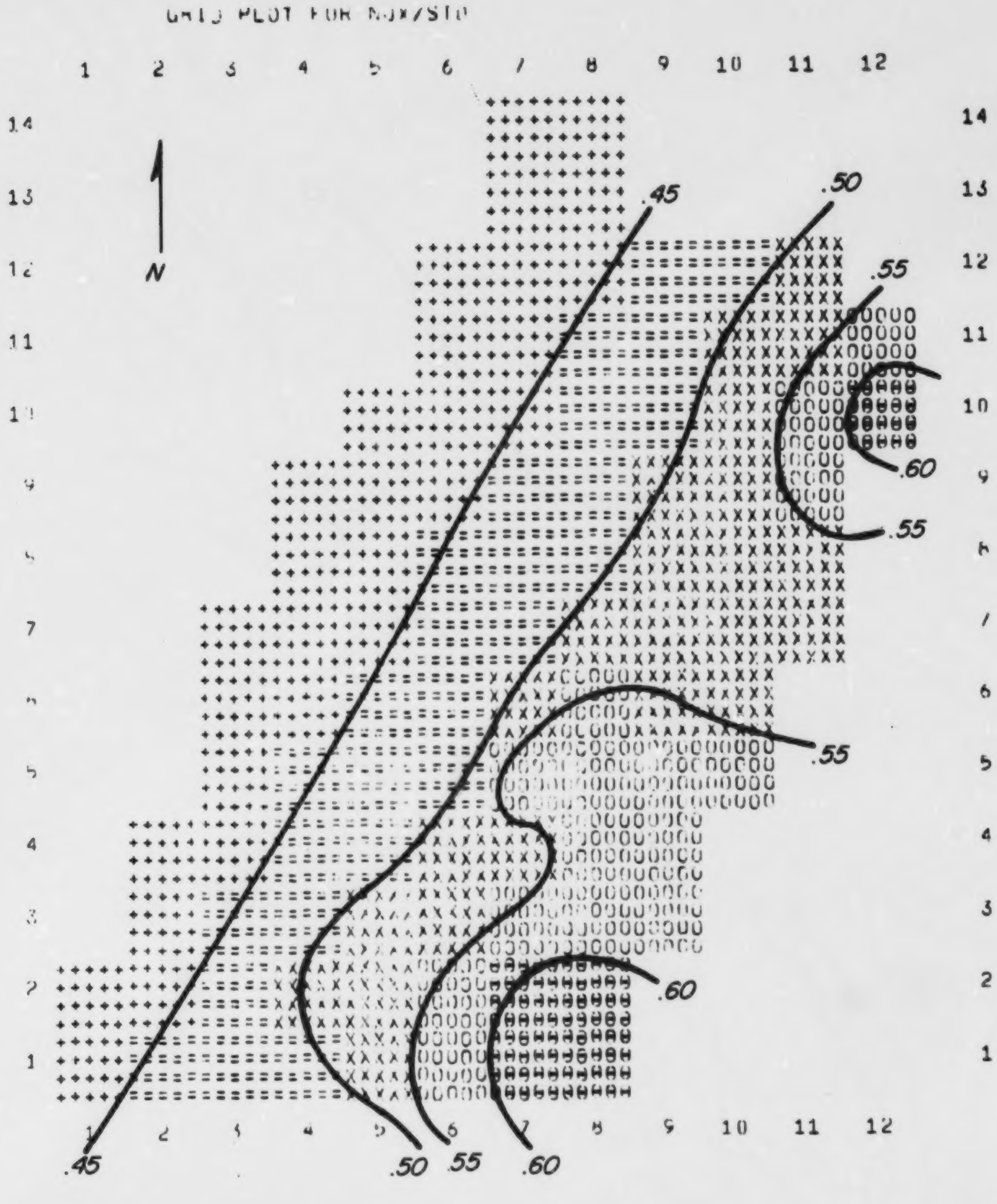

GRID PLOT FOR NOX/STD
1 2 3 4 5 6 7 8 9 10 11 12
14 13 12 11 10 9 8 7 6 5 4 3 2 1
N
.45
.50
.55
.60
.55
.55
.60
.45
.50
.55
.60

Figure 26 Air Quality Contours for Nitrogen Oxides for Plan 1B, Expressed as the Ratio of Air Quality/Air Quality Standard

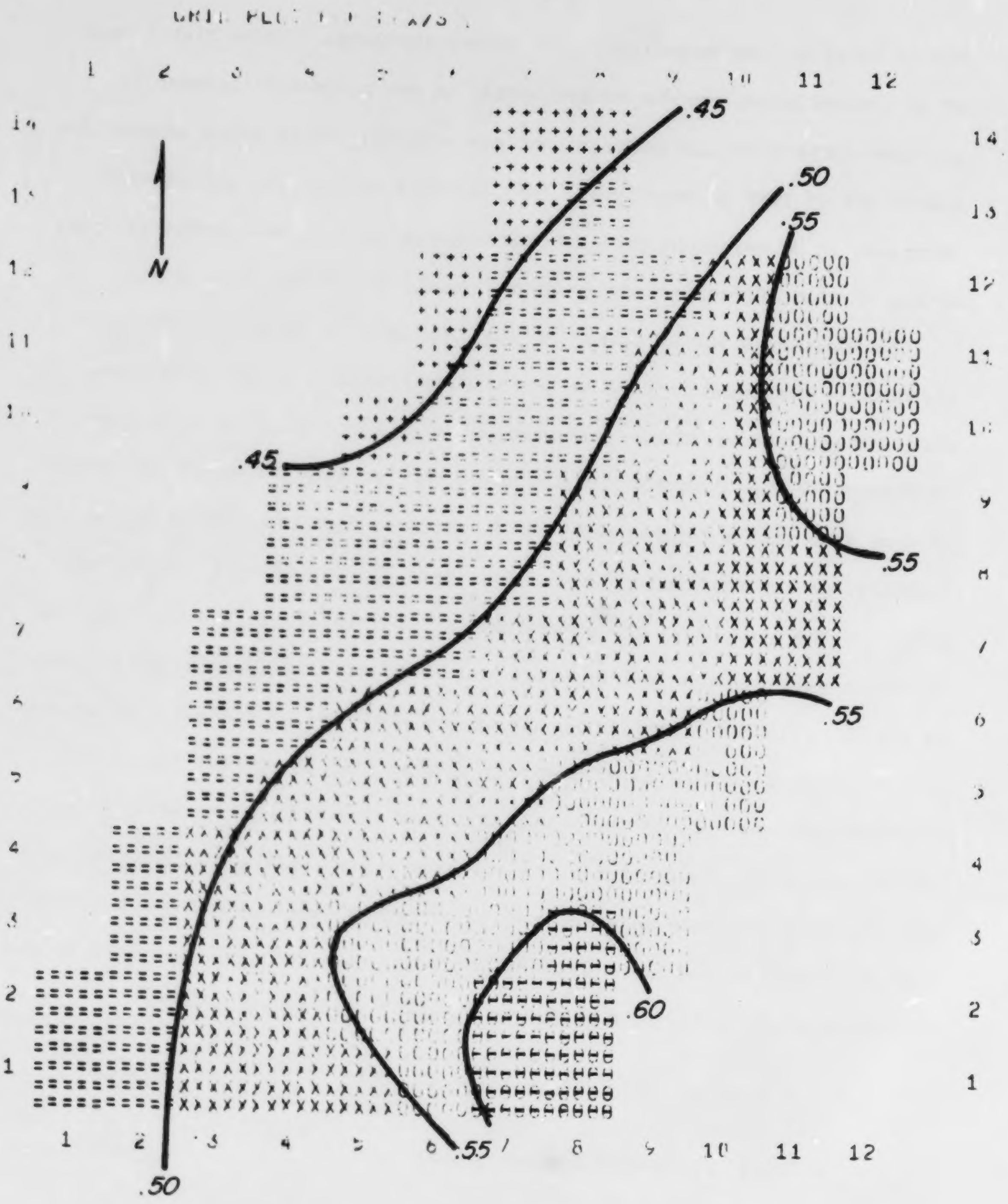

N
.45
.45
.50
.50
.55
.55
.55
.55
.60
1
2
3
4
5
6
7
8
9
10
11
12
14
13
12
11
10
9
8
7
6
5
4
3
2
1

Figure 27 Air Quality Contours for Nitrogen Oxides for Plan 1C, Expressed as the Ratio of Air Quality/Air Quality Standard

99% of total HC concentrations, also exceed standards. These high levels of HC concentration are due predominantly to the projected increase in emission factors for areawide solvent evaporations, which alone account for nearly 50% of 1990 HC emissions. This increase offsets the anticipated decreases in HC emissions from automobiles and point source industrial processes so that 1990 emission levels are nearly 2/3 of the 1970 levels.

An additional way of examining the compliance of land use plans with air quality standards is to examine the amount of area within each plan which exceeds the standards. In particular, the curves shown in Figures 28 through 32 show directly for each plan and for each pollutant the amount of land area within the planning region which exceeds the ambient air quality standard, or any fraction thereof. In Figure 29, for example, curves are given for the four plans for concentrations in relation to the SO_2 standard. These curves show, for example, that nearly 99% of Plan 1C area exceeds 40% of the SO_2 standard. Similarly, 85% of the land area of Plan 1A exceeds 40% of the standard, while 75% of the land area of Plan 1B exceeds 40% of the standard, and only 60% of the total land area within Plan 1 exceeds 40% of the SO_2 standard. Consequently these curves conveniently and quantitatively show the amount of land area exposed to any given level of pollutant concentration. The basic data on which these curves are based were generated by the LANTRAN program, and are tabulated in Tables 7 through 11.

6.3.2 Impact on Regional Air Quality

6.3.2.1 Background Concentrations

In order to analyze total air quality within the Meadowlands it is necessary to project not only pollutant concentrations resulting directly

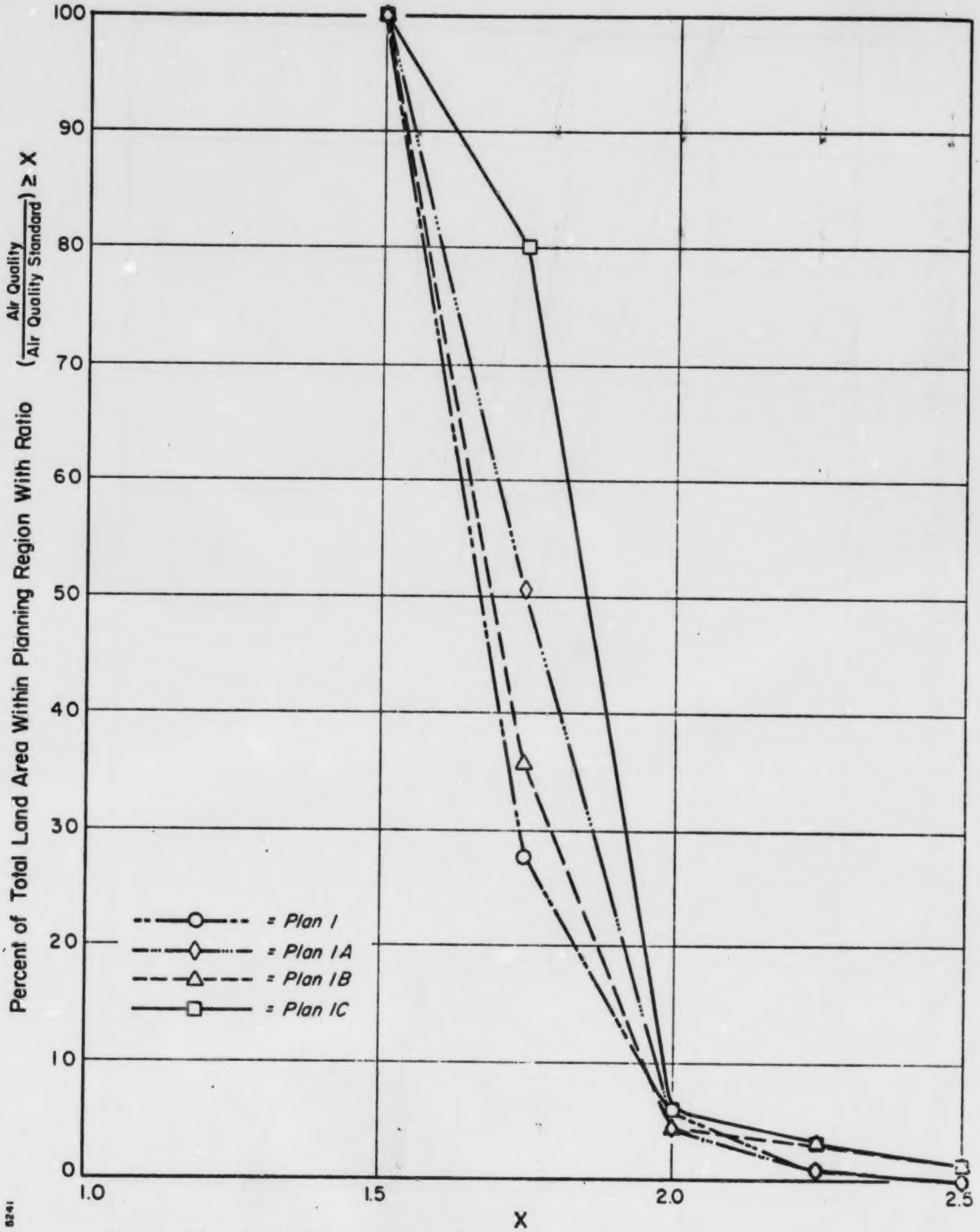


Figure 28 Regional Air Quality Cumulative Frequency Distribution for Total Suspended Particulates (TSP)

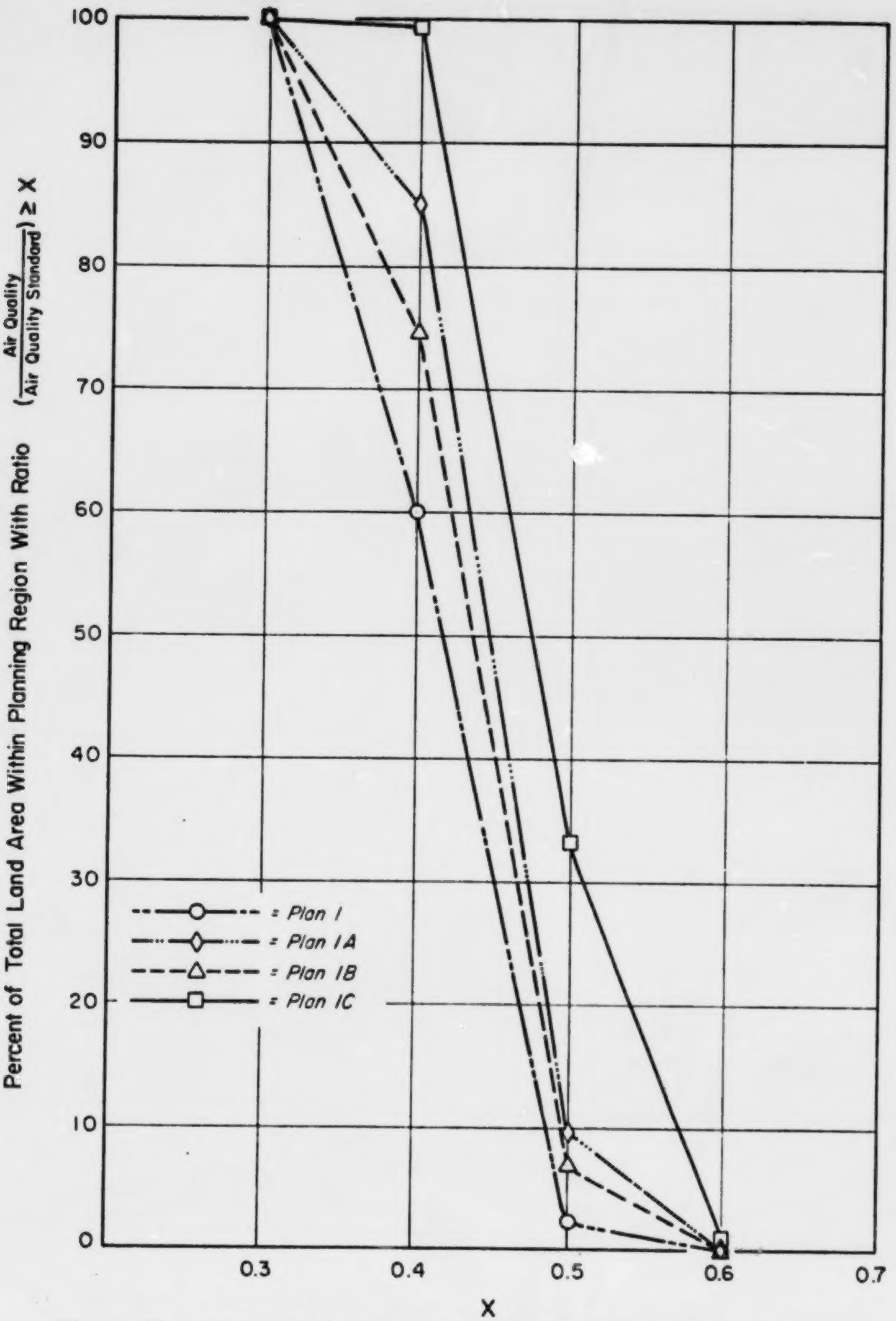


Figure 29 Regional Air Quality Cumulative Frequency Distribution for Sulphur Dioxide (SO_2)

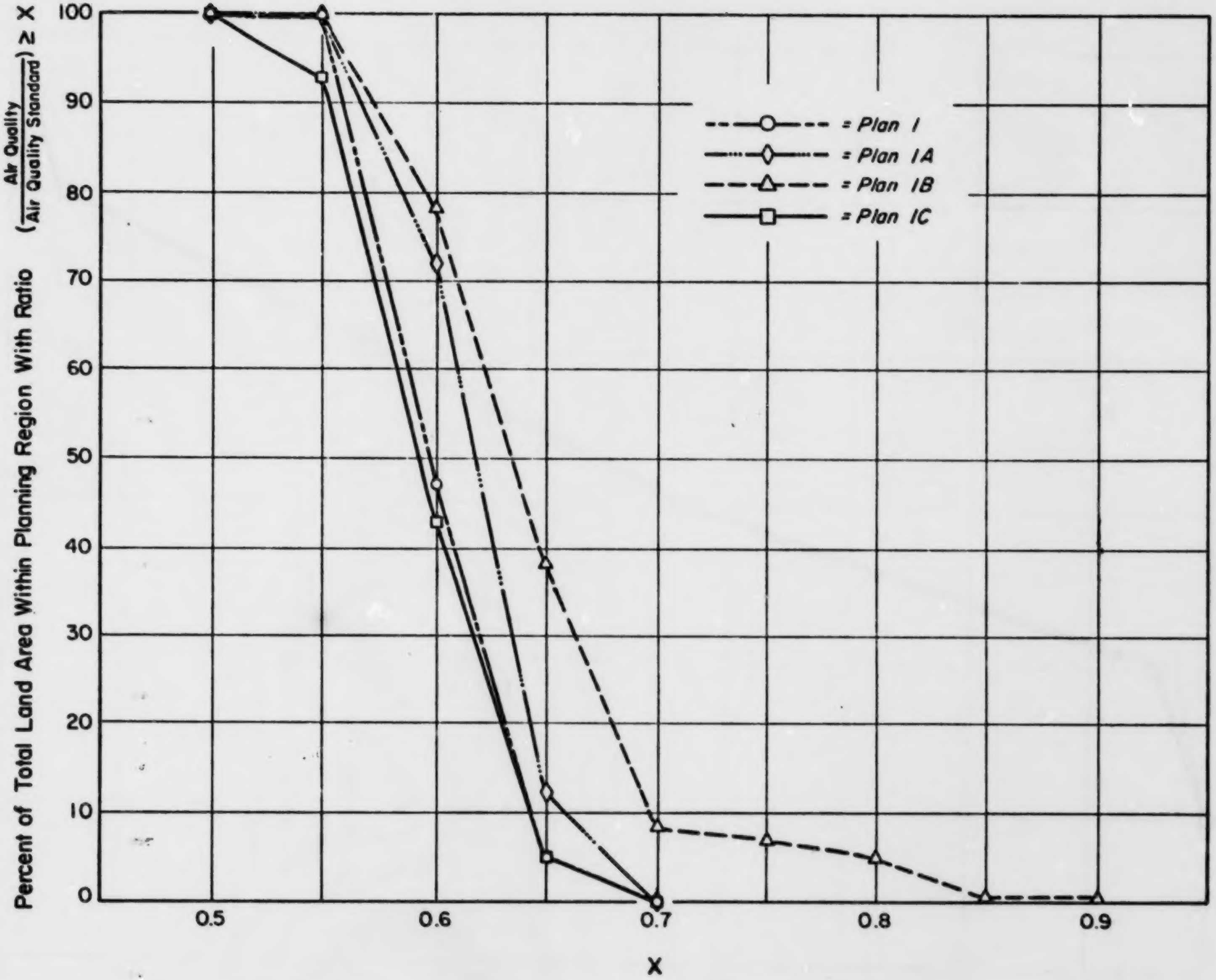


Figure 30 Regional Air Quality Cumulative Frequency for Carbon Monoxide (CO)

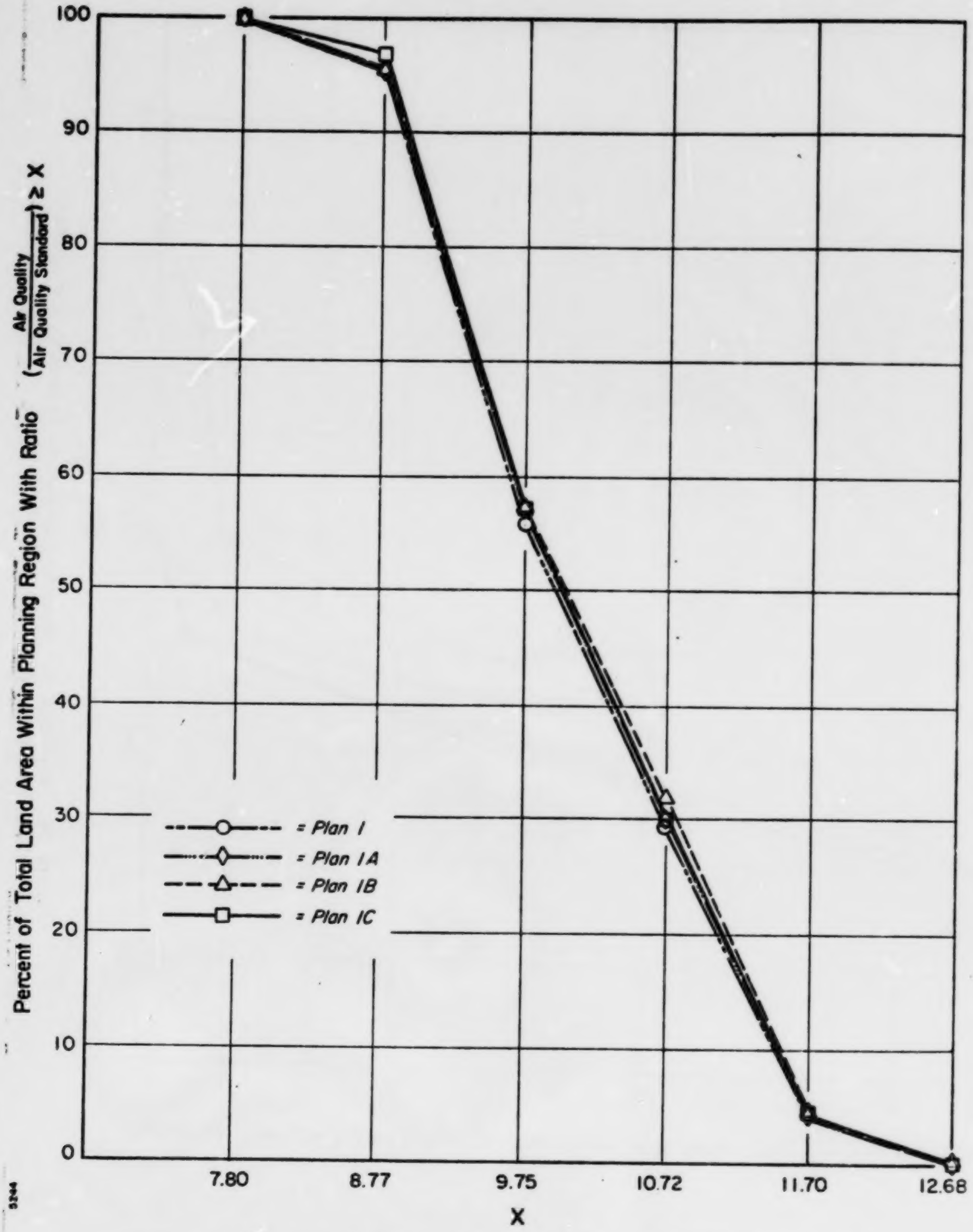


Figure 31 Regional Air Quality Cumulative Frequency Distribution for Hydrocarbons (HC)

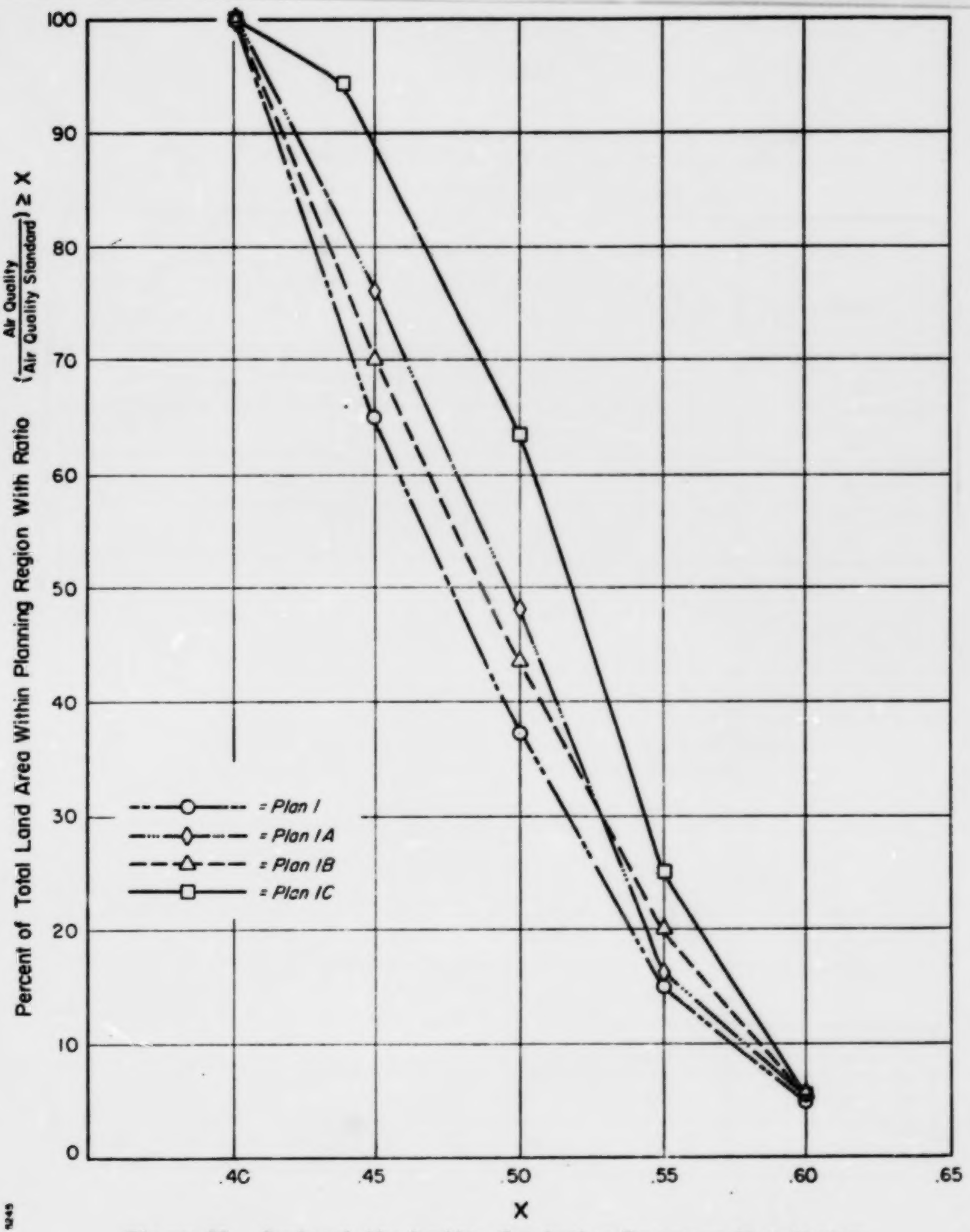


Figure 32 Regional Air Quality Cumulative Frequency Distribution for Nitrogen Oxides (NO_x)

TABLE 7

FREQUENCY DISTRIBUTION OF PERCENT OF TOTAL LAND AREA WITH $X_1 <$ AIR QUALITY/AIR QUALITY STANDARD $\leq X_2$ FOR TOTAL SUSPENDED PARTICULATES (TSP)

PLAN	Frequency Distribution Intervals (X_1 to X_2)				
	1.50 to 1.75	1.75 to 2.00	2.00 to 2.25	2.25 to 2.50	2.50 to 2.75
1	73	23	3	1	0
1A	49	47	3	1	0
1B	62	32	1	2	1
1C	20	24	3	2	1

CUMULATIVE DISTRIBUTION OF PERCENT OF TOTAL LAND AREA WITH AIR QUALITY/AIR QUALITY STANDARD $\geq X_1$ FOR TOTAL SUSPENDED PARTICULATES (TSP)

PLAN	Cumulative Distribution Intervals (X_1)				
	1.50 to 1.75	1.75 to 2.00	2.00 to 2.25	2.25 to 2.50	2.50 to 2.75
1	100	27	4	1	0
1A	100	51	4	1	0
1B	100	36	4	3	1
1C	100	80	6	3	1

TABLE 8

FREQUENCY DISTRIBUTION OF PERCENT OF TOTAL LAND AREA WITH $X_1 <$ AIR QUALITY/AIR QUALITY STANDARD $\leq X_2$ FOR SULFUR DIOXIDE (SO_2)

PLAN	Frequency Distribution Intervals (X_1 to X_2)			
	0.3 to 0.4	0.4 to 0.5	0.5 to 0.6	0.6 to 0.7
1	40	58	2	0
1A	15	75	9	0
1B	26	67	7	0
1C	1	66	32	1

CUMULATIVE DISTRIBUTION OF PERCENT OF TOTAL LAND AREA WITH AIR QUALITY/AIR QUALITY STANDARD $\geq X_1$ FOR SULFUR DIOXIDE (SO_2)

PLAN	Cumulative Distribution Intervals (X_1)			
	0.3 to 0.4	0.4 to 0.5	0.5 to 0.6	0.6 to 0.7
1	100	60	2	0
1A	100	85	9	0
1B	100	74	7	0
1C	100	99	33	1

TABLE 9

FREQUENCY DISTRIBUTION OF PERCENT OF TOTAL LAND AREA WITH $X_1 <$ AIR QUALITY/AIR QUALITY STANDARD $\leq X_2$

FOR CARBON DIOXIDE (CO)

PLAN	Frequency Distribution Intervals (X_1 to X_2)								
	0.50 to 0.55	0.55 to 0.60	0.60 to 0.65	0.65 to 0.70	0.70 to 0.75	0.75 to 0.80	0.80 to 0.85	0.85 to 0.90	0.90 to 0.95
1	1	52	43	4	0	0	0	0	0
1A	0	28	60	12	0	0	0	0	0
1B	0	22	40	30	1	2	4	0	1
1C	7	50	39	4	0	0	0	0	0

CUMULATIVE DISTRIBUTION OF PERCENT OF TOTAL LAND AREA WITH AIR QUALITY/AIR QUALITY STANDARD $\geq X_1$

FOR CARBON DIOXIDE (CO)

PLAN	Cumulative Distribution Intervals (X_1)								
	0.50 to 0.55	0.55 to 0.60	0.60 to 0.65	0.65 to 0.70	0.70 to 0.75	0.75 to 0.80	0.80 to 0.85	0.85 to 0.90	0.90 to 0.95
1	100	99	47	4	0	0	0	0	0
1A	100	100	72	12	0	0	0	0	0
1B	100	100	78	38	8	7	5	1	1
1C	100	93	43	4	0	0	0	0	0

TABLE 10

FREQUENCY DISTRIBUTION OF PERCENT OF TOTAL LAND AREA WITH $X_1 <$ AIR QUALITY/AIR QUALITY STANDARD $\leq X_2$

FOR HYDROCARBONS (HC)

PLAN	Frequency Distribution Intervals (X_1 to X_2)				
	1.80 to 8.77	8.77 to 9.75	9.75 to 10.72	10.72 to 11.70	11.70 to 12.68
1	4	40	27	25	4
1A	4	39	27	26	4
1B	4	39	25	28	4
1C	3	40	27	26	4

CUMULATIVE DISTRIBUTION OF PERCENT OF TOTAL LAND AREA WITH AIR QUALITY/AIR QUALITY STANDARD $\geq X_1$

FOR HYDROCARBONS (HC)

PLAN	Cumulative Distribution Intervals (X_1)				
	7.80 to 8.77	8.77 to 9.75	9.75 to 10.72	10.72 to 11.70	11.70 to 12.68
1	100	96	56	29	4
1A	100	96	57	30	4
1B	100	96	57	32	4
1C	100	97	57	30	4

TABLE 11

FREQUENCY DISTRIBUTION OF PERCENT OF TOTAL LAND AREA WITH $X_1 <$ AIR QUALITY/AIR QUALITY STANDARD $\leq X_2$ FOR NITROGEN OXIDES (NO_x)

PLAN	Frequency Distribution Intervals (X_1 to X_2)				
	0. 40 to 0.45	0.45 to 0.50	0.50 to 0.55	0.55 to 0.60	0.60 to 0.65
1	35	28	22	11	4
1A	23	29	32	11	5
1B	30	27	23	15	5
1C	6	31	38	20	5

CUMULATIVE DISTRIBUTION OF PERCENT OF TOTAL LAND AREA WITH AIR QUALITY/AIR QUALITY STANDARD $\geq X_1$ FOR NITROGEN OXIDES (NO_x)

PLAN	Cumulative Distribution Intervals (X_1)				
	0.40 to 0.45	0.45 to 0.50	0.50 to 0.55	0.55 to 0.60	0.60 to 0.65
1	100	65	37	15	4
1A	100	76	48	16	5
1B	100	70	43	20	5
1C	100	94	63	25	5

from sources of emissions within the Meadowlands but also concentrations influencing the Meadowlands region resulting from sources of emissions outside the Meadowlands region (i.e., the background sources). For the purpose of this analysis the background includes specifically sources outside the Hackensack Meadowlands District as well as regional network traffic including those links within the Hackensack Meadowlands District for which long-range projections have already been made by the New Jersey Department of Transportation. By definition, the background also includes existing major point sources within the Hackensack Meadowlands District since they are common to all plans.

The specific method for calculating and projecting background emissions to the 1990 time period are described in detail in the Task 1 Report. The MARTIK program of the AQUIP System was used to calculate air quality concentrations for background sources and the SYMAP routine was used to display graphically the results. The resultant air quality contour patterns for annual average concentrations for the five pollutants under consideration are shown in Figures B1 through B5 of Appendix B to this report.

The analysis of background air quality indicates that it is a dominant influence on regional air quality within the Meadowlands. As illustrated in Table 6, the background pollutant concentrations range from 65% to 99% of the total concentration levels within the Meadowlands planning region, depending upon the particular pollutant and plan. Furthermore, the spatial patterns of the background air quality concentrations are shown to account for the predominant north-south orientation of the contours and the increase in air quality levels from west to east. The general variation of background air quality contours over the Meadowlands region indicates both the strong influence of pollution from the New York City urban core region on the Meadowlands, and the influence of meteorological conditions, especially the prevailing westerly winds.

Since background concentrations for each pollutant have such strong spatial variations within the Meadowlands, it is evident that consideration of background is highly important in locating land-use categories and major sources of emissions within a land use plan, both to minimize impacts on critical receptors and to avoid adding to existing regional problems. It is also evident that since background concentrations represent such a high percentage of total air quality within the Meadowlands for any given plan, the resultant variation among plans in total air quality will be extremely small. For example, a 100% variation in emissions resulting from alternative land use plans may cause only a 10% change in total regional air quality levels. As a consequence it may be concluded that while consideration of background pollutant concentrations is essential for plans in the vicinity of major urbanized areas, nevertheless land use planning is an ineffective device for abatement of regional air pollution unless the planning region is sufficiently large that "background" concentration levels represent only a small percentage (for example, less than 50%) of total air quality levels.

6.3.2.2 Analysis of Total Air Quality Contours

Total pollutant concentrations for summer, winter, and annual averages were calculated by adding the background to individual plan contributions. Emission sources for each plan include major new point sources, new line (roadway) sources, and gridded area sources. The methodologies for projecting the plan emissions data and the listing of the resultant emissions data are described in the Task 1 Report. The MARTIK program within the AQUIP System was used to calculate pollutant concentrations from the plan emissions and the results were added to the previously calculated background air quality concentrations to get total air quality for each plan. The SYMAP program was used to produce computer-generated displays of air quality concentration patterns. Specifically, isopleth air quality contours for each of the four plans, five pollutants, and three seasons (that is, annual concentration averages plus summer and winter seasonal averages) are shown in Figures B6 through B65 in Appendix B.

The visual correlation of the air quality contours illustrated in Figures B6 to B65 (or alternatively the isopleths of the AQ/AAQS ratios illustrated in Figures 8 to 11) with the location of land uses for each plan as illustrated in Figures 3 to 6 show the impact of land uses on the spatial patterns of regional air quality. This analysis shows distinct variations in contours among the different plans for each pollutant (except for hydrocarbons) despite the previously acknowledged high levels of background concentrations.

In particular, comparison of the isopleth contours for mean annual TSP concentrations (Figures 8 to 11) indicate that the best air quality is given by Plan 1 followed by Plans 1B, 1A, and 1C. In general, the contours are predominantly in a north-south direction with concentrations increasing from west to east. These general characteristics (common to all plans) are clearly attributable to the dominant influence of the background. Examination of the plan to plan variations in TSP concentrations, however, indicates that the dominant influence on the shape of the contours is due to the location and amount of land use devoted to manufacturing. This is especially evident from the comparison of the contours for Plans 1A and 1B. In these plans, which have essentially equivalent percent mixes of land uses, the air quality contours are significantly worse in Plan 1A and are strongly correlated with the concentration of manufacturing activities in one general location within the plan. By contrast the manufacturing activities in Plan 1B are widely dispersed within the plan.

The corresponding examination of SO_2 contours (Figures 12 to 15) indicates that Plan 1 has the least concentrations throughout the region, followed by Plans 1B, 1A, and 1C. The contours in each plan show clearly the influence of the airport. Similarly, the examination of the shifts in air quality contours (particularly in Plans 1A, 1B, and 1C) shows a very strong correlation with the location and amount of manufacturing land use activity. Also, other general characteristics of these contours which show the strong influence of background concentrations, are similar to those for TSP.

Air quality contours for NO_X (Figures 24 to 27 also show characteristic patterns and correlations with land uses which are similar to those for both TSP and SO_2. Likewise, Plan 1 has best regional air quality for NO_X, followed by Plans 1B, 1A, and 1C.

The isopleth contours for CO concentrations (Figures 16 to 19) show entirely different characteristics in spatial patterns and in correlations with land uses for the four plans. Lowest regional concentration levels occur for Plan 1C followed in order of increasing regional concentrations by Plans 1, 1A and 1B. Not only does this ranking follow the order of increasing levels of vehicle trip miles (as indicated in Table 3), but also the variations in the shape of the contours is strongly correlated with the location of major new arterials within the plans. This is especially noticeable in Plans 1A and 1B, which have the highest population, the most residential area, and the most distinctive patterns of new arterial roadways serving these residential areas. As a consequence, it is observed that air quality contours for CO are indirectly related to the location of highly populated residential areas.

Finally, the plan by plan comparison for air quality contours for HC (Figures 20 to 23)* shows an almost undetectable change in concentration levels and spatial patterns. This indicates that the plans have absolutely no influence on HC concentrations or spatial patterns in the Meadowlands; air quality is determined entirely by regional background levels.

It is concluded from this visual analysis of air quality contours that the major impact on regional pollutant concentration levels and on the spatial distribution of these concentrations is due to the relative percentage of land use devoted to manufacturing and to transportation activities. This is supported by the data presented in Table 12 which lists the total annual emissions per acre for each land use category studied for the 1990 Meadowlands Land Use Plans. This table shows that those land use categories having the largest emissions per unit land area are manufacturing (for TSP, SO_2 and NO_x) and transportation (for CO); all other land use categories have relatively small emissions per unit area. Consequently all other land use categories for each plan contribute only a negligible influence on the shape of the air quality contours regardless of the relative location of the land use within the planning region.

The visual examination of pollutant air quality contours for each of the plans also indicates the importance of the relative location of land uses within the plans. This is conveniently illustrated by comparing Plans 1A and 1B since the relative mix of land uses is quite similar for both plans.

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*See pages 110 to 113

TABLE 12

SUMMARY OF 1990 ANNUAL EMISSIONS PER ACRE FOR HACKENSACK MEADOWLANDS LAND USE CATEGORIES

Land Use Category	Pollutant Emissions (lb/year/ acre)				
	TSP	SO_2	CO	HC	NO_X
Residential					
10 DU/AC	24.0	1.2	36.0	12.0	7.2
20 DU/AC	180.0	117.0	3.6	54.0	86.5
30 DU/AC	180.0	117.0	3.6	54.0	86.5
50 DU/AC	250.0	162.5	5.0	75.0	120.0
80 DU/AC	210.0	136.5	4.2	63.0	100.8
Commercial & Industrial					
Comm.	60.0	44.0	0.8	12.0	96.0
Mfg.					
light	1080.0	1128.0	9.4	141.0	845.0
heavy	5400.0	5400.0	60.0	900.0	5400.0
Research	2.25	16.5	0.3	4.5	36.0
Distribution	60.0	44.0	0.8	12.0	96.0
Special Use	60.0	44.0	0.8	12.0	96.0
Airport	100.0	1000.0	3000.0	350.0	100.0
Transport Center	180.0	132.0	2.4	36.0	288.0
Cultural Center	45.0	33.0	0.6	9.0	72.0
Open Space	0	0	0	0	0
Other(2)		--	Emission	Factors --	
Highway (lb/10^6 VTM)	700	400	11,000	1,000	1,500
Stadium (lb/10^3 hrs idling)	4.3	4.4	12.2	2.7	0.9

(1) Assumes 400,000 flights/year from Teterboro Airport, and 700 acre area.

(2) N.B. Activities not specified on basis of emissions per unit area.

As previously observed, the location of nearly all manufacturing activities within a concentrated region in the southern part of the Meadowlands in Plan 1A generally causes pollutant concentrations for TSP, SO_2, and NO_X to be worse than for Plan 1B where the distribution and manufacturing activities are more widely dispersed throughout the plan. It is also observed that the high density residential area in Plan 1A is located in the eastern part of the Meadowlands where pollutant concentration levels generally are highest. By contrast in Plan 1B the predominant location of populated areas is in the western part of the region where pollutant concentration levels generally are significantly lower. Moreover, it is observed that this shift in the relative location of residential areas has little influence on the concentration levels for TSP, SO_2 and NO_X. This would indicate a reasonable degree of freedom on the part of the planner to shift the relative location of residential areas to minimize localized impacts on population, students and other critical receptors without significantly changing regional air quality concentration levels or patterns.

The corresponding examination of air quality contours for CO shows distinctly different characteristics for Plans 1A and 1B. In this case air quality concentrations are primarily influenced by the location of major roadways and by the amount of vehicle trip miles for each plan. Furthermore to the extent that roadways are used to service residential areas, the location of residential areas will influence CO air quality contours. Even so, it is apparent that since CO concentration levels generally increase from west to east, those plans (such as Plan 1B) having more population concentrated in the western parts of the Meadowlands will have fewer people exposed to the higher CO concentration levels.

Likewise, since the background levels of HC are so high that there is no significant variation in air quality among the plans, those plans having most of the population located in the western parts of the region will have the least impact on population.

6.3.2.3 Quantitative Comparison of Plans by Pollutant

In addition to the above efforts to analyze the regional air quality on the basis of the visual examination of air quality contours, a significant portion of the analysis focused on quantifying the impact of the alternative land use plans on regional air quality in terms of the impact measures defined in Section 5.2.3. In particular, the impact measures included both the integrated total area exposure and the average total area exposure which differ only by a constant since the total area of the planning region is constant.

The impact measures for both integrated and average total area exposures were calculated from the LANTRAN output data associated with Figures 8 to 27,* which show mean annual pollutant concentrations for each 1 km^2 grid cell within the Meadowlands for each plan and each pollutant. The impact measures for the integrated total area exposure are given in Table 13, and the corresponding average total area exposure values are given in Table 14.

These impact measures show quantitatively the levels of regional air quality for each of the four plans and can be used to evaluate the air quality impact of different plans. In the analysis such quantitative comparisons of alternative plans were made on a pollutant by pollutant basis by forming the "relative ratios" of the impact measures for each plan. This was done by assigning a relative ratio of 1.0 to the plan with the smallest impact measure and forming corresponding ratios for other plans relative to their impact measures. The resultant relative ratios for each pollutant

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*See pages 98 to 118

TABLE 13
INTEGRATED RECEPTOR EXPOSURE IMPACT MEASURES

RECEPTOR	PLAN	POLLUTANT				
		TSP ($\mu g/m^3$)	SO_2 (ppm)	CO (ppm)	HC ($\mu g/m^3$)	NO_x ($\mu g/m^3$)
TOTAL AREA (Acres)	1	2.78E06	1.98E02	1.76E04	3.79E07	1.14E06
	1A	2.88E06	2.10E02	1.82E04	3.80E07	1.18E06
	1B	2.83E06	2.04E02	1.89E04	3.81E07	1.17E06
	1C	3.06E06	2.27E02	1.75E04	3.81E07	1.22E06
POPULATION (Persons)	1	1.70E07	1.18E03	1.09E05	2.33E08	6.85E06
	1A	5.08E07	3.64E03	3.19E05	6.84E08	2.06E07
	1B	5.99E07	3.91E03	3.67E05	7.26E08	2.21E07
	1C	1.06E06	7.68E01	6.21E03	1.35E07	4.21E05
STUDENTS (Persons)	1	2.92E06	2.03E02	1.89E04	3.97E07	1.17E06
	1A	7.41E06	5.29E02	4.65E04	9.91E07	3.00E06
	1B	1.34E07	9.55E02	9.01E04	1.78E08	5.41E06
	1C	0.00	0.00	0.00	0.00	0.00
RESIDENTIAL AREA (Acres)	1	1.45E05	10.1	9.31E02	1.99E06	5.84E04
	1A	4.06E05	28.8	2.57E03	5.41E06	1.64E05
	1B	4.89E05	34.8	3.27E03	6.47E06	1.96E05
	1C	2.96E04	2.13	1.73E02	3.76E05	1.17E04
OPEN SPACE (Acres)	1	7.20E05	50.6	4.64E03	9.84E06	2.94E05
	1A	4.23E05	29.9	2.68E03	5.60E06	1.71E05
	1B	4.08E05	28.8	2.74E03	5.50E06	1.66E05
	1C	2.20E05	16.4	1.26E03	2.75E06	8.87E04
COMMERCIAL and INDUSTRIAL AREA (Acres)	1	1.09E06	78.2	6.98E03	1.49E07	4.47E05
	1A	9.66E05	70.0	6.10E03	1.26E07	3.92E05
	1B	1.03E06	75.7	6.93E03	1.41E07	4.33E05
	1C[2]	4.87E05	36.7	2.80E03	5.93E06	1.92E05

TABLE 14
AVERAGE RECEPTOR EXPOSURE IMPACT MEASURES

RECEPTOR	PLAN	POLLUTANT				
		TSP ($\mu g/m^3$)	SO_2 (ppm)	CO (ppm)	HC ($\mu g/m^3$)	NO_x ($\mu g/m^3$)
TOTAL AREA (Acres)	1	1.42E02	0.0101	0.898	1.93E03	58.237
	1A	1.49E02	0.0107	0.928	1.94E03	60.086
	1B	1.45E02	0.0104	0.965	1.95F03	59.633
	1C	1.56E02	0.0116	0.891	1.94E03	62.363
POPULATION (Persons)	1	1.15E02	0.0080	0.74	1.58E03	46.4
	1A	1.24E02	0.0090	0.78	1.68E03	50.5
	1B	1.17E02	0.0083	0.78	1.55E03	47.0
	1C	1.30E02	0.0094	0.76	1.65E03	51.6
STUDENTS (Persons)	1	1.13E02	0.0079	0.73	1.54E03	45.4
	1A	1.24E02	0.0088	0.78	1.66E03	50.3
	1B	1.17E02	0.0083	0.79	1.55E03	47.2
	1C	0.00	0.00	0.00	0.00	0.00
RESIDENTIAL AREA (Acres)	1	1.16E02	0.0081	0.74	1.59E03	46.8
	1A	1.23E02	0.0087	0.78	1.64E03	49.6
	1B	1.17E02	0.0083	0.78	1.55E03	46.9
	1C	1.31E02	0.0094	0.77	1.67E03	51.8
OPEN SPACE (Acres)	1	1.17E02	0.0082	o.75	1.60E03	44.6
	1A	1.22E02	0.0086	0.78	1.62E03	49.6
	1B	1.18E02	0.0084	0.80	1.60E03	48.3
	1C	1.30E02	0.0097	0.74	1.63E03	52.4
COMMERCIAL and INDUSTRIAL AREA (Acres)	1	1.16E02	0.0083	0.74	1.59E03	47.6
	1A	1.21E02	0.0087	0.76	1.57E03	49.0
	1B	1.20E02	0.0087	0.81	1.64E03	50.4
	1C	1.29E02	0.0097	0.74	1.57E03	50.6

for the four plans are listed in Table 15 for the integrated total area exposure impact parameter and in Table 16 for the average total area exposure impact parameter.

These relative ratios show directly the percent variation among plans in the impact on mean annual regional air quality levels for a specific pollutant. For example, since the average total area exposure impact parameter for SO_2 has the minimum value for Plan 1, Table 16 shows the relative ratio of 1.0 for Plan 1, and relative ratios of 1.059, 1.032 and 1.149 for Plans 1A, 1B and 1C, respectively. The direct interpretation of these relative ratios is that the average SO_2 concentration over the Meadowlands region for Plan 1A is 5.9% greater than the corresponding average for Plan 1 (i.e., air quality is 5.9% worse). Likewise, the average regional concentration level of SO_2 for Plan 1B is 3.2% greater than Plan 1; and for Plan 1C the average regional SO_2 concentration is 14.9% greater than for Plan 1. Thus the relative ratio shows that there is a nearly 15% variation among plans in terms of regional air quality for SO_2.

These relative ratios can be used not only to show the percent variation among the plans in terms of impact on air quality, but also can be used as a means of ranking the plans for a specified pollutant. Table 17 lists in the order from best to worst the ranking of plans for each pollutant (and for each impact parameter, namely, for integrated and average total area exposures).

The results of the analysis of each plan on a pollutant by pollutant basis using these quantitative measures of impact generally show a very good agreement between the quantitative ranking of plans and the subjective ranking of plan based on the visual examination of the pollutant contour

TABLE 15
RELATIVE RANKING RATIO OF INTEGRATED RECEPTOR EXPOSURE RATIO(1)

RECEPTOR or LAND USE	PLAN	POLLUTANT				
		TSP	SO_2	CO	HC	NO_x
TOTAL AREA	1	1.000	1.000	1.008	1.000	1.000
	1A	1.039	1.059	1.042	1.005	1.032
	1B	1.021	1.032	1.084	1.007	1.024
	1C	1.101	1.149	1.000	1.006	1.071
POPULATION	1	16.038	15.410	17.619	17.259	16.271
	1A	47.925	47.373	51.357	50.667	48.931
	1B	51.792	50.915	59.058	53.778	52.494
	1C	1.000	1.000	1.000	1.000	1.000
STUDENTS	1	1.000	1.000	1.000	1.000	1.000
	1A	2.538	2.606	2.466	2.496	2.564
	1B	4.589	4.699	4.772	4.484	4.624
	1C(2)	–	–	–	–	–
RESIDENTIAL LAND AREA	1	4.894	4.732	5.382	5.293	4.996
	1A	13.727	13.535	14.832	14.388	13.994
	1B	16.526	16.329	18.902	17.207	16.781
	1C	1.000	1.000	1.000	1.000	1.000
OPEN SPACE AREA	1	3.271	3.094	3.694	3.578	3.089
	1A	1.920	1.825	2.137	2.036	1.931
	1B	1.853	1.759	2.186	2.000	1.875
	1C	1.000	1.000	1.000	1.000	1.000
COMMERCIAL and INDUSTRIAL AREA	1	2.238	2.131	2.497	2.513	2.333
	1A	1.984	1.909	2.184	2.125	2.046
	1B	2.115	2.064	2.481	2.378	2.258
	1C(3)	1.000	1.000	1.000	1.000	1.000

(1) Ratio is calculated for a given pollutant by dividing the integrated receptor exposure (persons or area X pollutant concentration) by the integrated receptor exposure of the particular plan having the smallest value. Ratio for a plan and a pollutant shows relative impact at a given pollutant among the various plans.

(2) Plan 1C has no student population specified.

(3) Values for Plan 1C are based on no contribution from distribution sources.

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TABLE 16
RELATIVE RANKING RATIO OF AVERAGE RECEPTOR EXPOSURE RATIO(1)

RECEPTOR or LAND USE	PLAN	POLLUTANT				
		TSP	SO_2	CO	HC	NO_x
TOTAL AREA	1	1.000	1.000	1.008	1.000	1.000
	1A	1.039	1.059	1.042	1.005	1.032
	1B	1.021	1.032	1.084	1.007	1.024
	1C	1.101	1.149	1.000	1.006	1.071
POPULATION	1	1.000	1.000	1.000	1.021	1.000
	1A	1.081	1.023	1.054	1.085	1.088
	1B	1.015	1.038	1.055	1.000	1.014
	1C	1.125	1.171	1.027	1.070	1.112
STUDENTS	1	1.000	1.000	1.000	1.000	1.000
	1A	1.095	1.124	1.064	1.077	1.107
	1B	1.031	1.056	1.072	1.007	1.039
	1C(2)	-	-	-	-	-
RESIDENTIAL	1	1.000	1.000	1.000	1.030	1.000
	1A	1.062	1.083	1.043	1.060	1.060
	1B	1.008	1.031	1.049	1.000	1.003
	1C	1.132	1.171	1.030	1.078	1.109
OPEN SPACE AREA	1	1.000	1.000	1.017	1.003	1.000
	1A	1.044	1.049	1.046	1.015	1.111
	1B	1.010	1.014	1.074	1.000	1.083
	1C	1.110	1.174	1.000	1.018	1.176
COMMERCIAL and INDUSTRIAL AREA	1	1.000	1.000	1.007	1.013	1.000
	1A	1.037	1.048	1.030	1.003	1.026
	1B	1.032	1.058	1.093	1.047	1.057
	1C(3)	1.108	1.164	1.000	1.000	1.063

(1) Ratio is calculated for a given pollutant by dividing the average receptor exposure (in units of pollutant concentration) by the average exposure of the particular plan having the smallest value. Ratio for a plan and a pollutant shows relative impact of a given pollutant among the various plans.

(2) Plan 1C has no student population specified.

(3) Values for Plan 1C are based on no contribution from distribution sources.

TABLE 17
RELATIVE RANKING OF PLANS BY POLLUTANT ON BASIS OF QUANTITATIVE MEASURES OF IMPACT

Impact Measure	Plan Rank (Best to Worst)	TSP		SO_2		CO		HC		NO_X	
		Plan	(Ratio)[1]	Plan	(Ratio)	Plan	(Ratio)	Plan	(Ratio)	Plan	(Ratio)
Integrated and average total area exposure	1	1	(1.000)	1	(1.000)	1C	(1.000)	1	(1.000)	1	(1.000)
	2	1B	(1.021)	1B	(1.032)	1	(1.008)	1A	(1.005)	1B	(1.024)
	3	1A	(1.039)	1A	(1.059)	1A	(1.042)	1C	(1.006)	1A	(1.032)
	4	1C	(1.101)	1C	(1.149)	1B	(1.084)	1B	(1.007)	1C	(1.071)
Integrated population exposure	1	1C	(1.0)	1C	(1.0)	1C	(1.0)	1C	(1.000)	1C	(1.000)
	2	1	(16.0)	1	(15.4)	1	(17.3)	1	(17.3)	1	(16.3)
	3	1A	(47.9)	1A	(47.4)	1A	(51.4)	1A	(50.7)	1A	(48.9)
	4	1B	(51.8)	1B	(50.9)	1B	(59.1)	1B	(53.8)	1B	(52.5)
Average population exposure	1	1	(1.000)	1	(1.000)	1	(1.000)	1B	(1.000)	1	(1.000)
	2	1B	(1.015)	1B	(1.038)	1C	(1.027)	1	(1.021)	1B	(1.014)
	3	1A	(1.081)	1A	(1.123)	1B	(1.053)	1C	(1.070)	1A	(1.088)
	4	1C	(1.128)	1C	(1.174)	1A	(1.054)	1A	(1.085)	1C	(1.112)
Integrated open space area exposure	1	1C	(1.000)	1C	(1.000)	1C	(1.000)	1C	(1.000)	1C	(1.000)
	2	1B	(1.853)	1B	(1.759)	1A	(2.137)	1B	(2.000)	1B	(1.875)
	3	1A	(1.920)	1A	(1.825)	1B	(2.186)	1A	(2.036)	1A	(1.931)
	4	1	(3.271)	1	(3.094)	1	(3.694)	1	(3.578)	1	(3.089)
Average open space area exposure	1	1	(1.000)	1	(1.000)	1C	(1.000)	1B	(1.000)	1	(1.000)
	2	1B	(1.010)	1B	(1.014)	1	(1.017)	1	(1.003)	1B	(1.083)
	3	1A	(1.044)	1A	(1.049)	1A	(1.046)	1A	(1.015)	1A	(1.111)
	4	1C	(1.110)	1C	(1.174)	1B	(2.074)	1C	(1.018)	1C	(1.176)
Integrated students exposure	1	1	(1.000)	1	(1.000)	1	(1.000)	1	(1.000)	1	(1.000)
	2	1A	(2.538)	1A	(2.606)	1A	(2.466)	1A	(2.496)	1A	(2.564)
	3	1B	(4.589)	1B	(4.699)	1B	(4.772)	1B	(4.484)	1B	(4.624)
	4		--(2)		--(2)		--(2)		--(2)		--(2)
Average students exposure	1	1	(1.000)	1	(1.000)	1	(1.000)	1	(1.000)	1	(1.000)
	2	1B	(1.031)	1B	(1.056)	1A	(1.064)	1B	(1.007)	1B	(1.039)
	3	1A	(1.095)	1A	(1.124)	1B	(1.072)	1A	(1.077)	1A	(1.107)
	4		--(2)		--(2)		--(2)		--(2)		--(2)
Integrated residential exposure	1	1C	(1.000)	1C	(1.000)	1C	(1.000)	1C	(1.000)	1C	(1.000)
	2	1	(4.894)	1	(4.732)	1	(5.382)	1	(5.293)	1	(4.996)
	3	1A	(13.727)	1A	(13.535)	1A	(14.832)	1A	(14.388)	1A	(13.994)
	4	1B	(16.526)	1B	(16.329)	1B	(18.902)	1B	(17.207)	1B	(16.731)
Average residential exposure	1	1	(1.000)	1	(1.000)	1	(1.000)	1B	(1.000)	1	(1.000)
	2	1B	(1.008)	1B	(1.031)	1C	(1.030)	1	(1.030)	1B	(1.003)
	3	1A	(1.062)	1A	(1.083)	1A	(1.043)	1A	(1.060)	1A	(1.060)
	4	1C	(1.132)	1C	(1.171)	1B	(1.049)	1C	(1.078)	1C	(1.109)
Integrated commercial and industrial area exposure	1	1C	(1.000)	1C	(1.000)	1C	(1.000)	1C	(1.000)	1C	(1.000)
	2	1A	(1.984)	1A	(1.909)	1A	(2.184)	1A	(2.125)	1A	(2.046)
	3	1B	(2.115)	1B	(2.064)	1B	(2.481)	1B	(2.378)	1B	(2.258)
	4	1	(2.238)	1	(2.131)	1	(2.497)	1	(2.513)	1	(2.333)
Average commercial and industrial area exposure	1	1	(1.000)	1	(1.000)	1C	(1.000)	1C	(1.000)	1	(1.000)
	2	1B	(1.032)	1A	(1.048)	1	(1.007)	1A	(1.003)	1A	(1.026)
	3	1A	(1.037)	1B	(1.058)	1A	(1.030)	1	(1.013)	1B	(1.057)
	4	1C	(1.108)	1C	(1.164)	1B	(1.093)	1B	(1.047)	1C	(1.063)

(1) Ratio of best plan is defined as unity; other ratios represent the relative values of the exposure parameter.
(2) Plan 1C has no student population specified.

patterns. For example, the quantitative ranking of plans for TSP gives (from best to worst) Plans 1, 1B, 1A, and 1C, respectively. Furthermore, the same ranking is given for SO_2 and NO_X, confirming the subjective ranking. The advantage of the quantitative procedure is that it shows the degree of variation among plans on air quality impact. For example, for particulates there is only a 10% variation among plans, while for SO_2 there is a 14.9% variation, and for NO_X a 7% variation. It is also observed for these three pollutants that average regional air quality for Plan 1B is no more than 2 to 3% worse than for Plan 1.

The visual ranking of plans for CO is also verified by the quantitative analysis. Table 17 indicates that Plan 1C is best, followed closely by Plan 1 (a less than 1% difference) and by Plans 1A and 1B. The subjective observations concerning HC concentrations are also verified by the quantitative analysis which shows that among all four plans the maximum variation is only 0.7%. Furthermore, the ranking (which was ambiguous in the visual analysis) is shown to be Plans 1, 1A, 1C, and 1B from best to worst, respectively.

6.3.2.4 Comparison of Plans for Combined Pollutant Impacts

In the previous portions of the analysis, the impact of land use plans on regional air quality concentration levels has been based either on the subjective visual examination of air quality contours or on the analysis of quantitative measures of impact. In both instances the alternative plans were compared on a pollutant by pollutant basis. To complete the comparison of plans it is necessary to rank the plans on the basis of multi-pollutant impacts on regional air quality. The "Normalized Impact Parameter" ranking index (described in Section 5.3.3) was used to measure the impact of all five pollutants combined in terms of the exposure of the total study area.

The computation of the Normalized Impact Parameter ranking index is based on a simple manual calculation and the results are shown in Table 18 for impact parameters based on integrated total area exposure and average total area exposure. The results of this multipollutant ranking of the alternative land use plans show that Plan 1 is best followed by Plans 1B, 1A, and 1C, respectively.

6.3.2.5 Impact of Open Space on Regional Air Quality

The sensitivity of regional air quality to the percent mix of land uses is shown by the following example which also illustrates the effectiveness of open space as a factor in air pollution considerations.

From Table 3 a comparison of the percent land use mix for the various plans shows that Plan 1 has 8% manufacturing and 8% research. It also has 31% open space and 6% residential area, for a total of 37% for these two categories. Plan 1A, on the other hand, has 14% manufacturing and no research. This plan has 18% open space and 17% residential area, a combined total of 35%. Finally, Plan 1B has 15% manufacturing and no research. It has 18% open space and 21% residential area for a combined total of 39%. If the 8% research category in Plan 1 were converted to an additional 8% manufacturing land use (for a total of 16% land use devoted to manufacturing in Plan 1) then, as indicated in Table 3, Plans 1, 1A, and 1B would be very similar in the percent land use mix except for the relative mix between open space and residential area.

As shown in Table 12 the dominant source of SO_2 emissions among the land use categories is manufacturing; emissions per unit area due to residential areas and research industrial categories are very much less by comparison. From the data in Tables 3 and 12 the total emissions of SO_2

TABLE 18

RELATIVE RANKING OF PLANS ON BASIS OF QUANTITATIVE RANKING INDEX FOR COMBINED POLLUTANT IMPACTS

PLAN RANK (Best to worst)	AVERAGE AREA EXPOSURE		AVERAGE POPULATION EXPOSURE		AVERAGE STUDENT EXPOSURE		AVERAGE RESIDENTIAL EXPOSURE		AVERAGE OPEN SPACE		AVERAGE COMMERCIAL AND INDUSTRIAL AREA EXPOSURE	
	Plan	Index(1)	Plan	Index	Plan	Index	Plan	Index	Plan	Index	Plan	Index
1	1	0.97	1	0.95	1	0.96	1	0.96	1	0.96	1	0.96
2	1B	1.00	1B	0.97	1B	1.00	1B	0.97	1B	0.99	1A	0.99
3	1A	1.004	1A	1.03	1A	1.05	1A	1.02	1A	1.01	1B	1.02
4	1C	1.03	1C	1.04	-(2)	-	1C	1.05	1C	1.07	1C	1.03

PLAN RANK (Best to worst)	INTEGRATED AREA EXPOSURE		INTEGRATED POPULATION EXPOSURE		INTEGRATED STUDENT EXPOSURE		INTEGRATED RESIDENTIAL EXPOSURE		INTEGRATED OPEN SPACE		INDUSTRIAL COMMERCIAL AND INDUSTRIAL AREA EXPOSURE	
	Plan	Index(1)	Plan	Index	Plan	Index	Plan	Index	Plan	Index	Plan	Index
1	1	0.968	1C	0.0332	1	0.49	1C	0.11	1C	0.48	1C	0.52
2	1B	0.996	1	0.540	1A	1.24	1	0.54	1B	0.93	1A	1.07
3	1A	1.002	1A	1.624	1B	2.27	1A	1.51	1A	0.95	1B	1.18
4	1C	1.028	1B	1.798	-(2)	-	1B	1.84	1	1.63	1	1.22

(1) Index = Normalized Impact Parameter Index (as defined in text).

(2) Plan 1C excluded - it has no students.

resulting directly from sources within Plan 1 can be calculated before and after the conversion of the 8% research land use category. The result is an estimated 73% increase in emissions due directly to sources in Plan 1. If it is further assumed that these additional emissions, which arise from 8% of the Meadowlands area, diffuse uniformly over the entire Meadowlands region, then average regional SO_2 concentrations generated by the plan itself will increase by 5.8%.

The data in Table 6 shows that background SO_2 concentrations for Plan 1 range between 35% and 55% of total regional SO_2 concentration levels. If it is arbitrarily assumed that the average background level is 45% of total air quality, then the net increase in average regional air quality within the Meadowlands planning region would be (1 - 0.45)5.8% or a total of 3.2%. Comparison of the relative ratios of average regional SO_2 concentrations for Plans 1, 1A, and 1B as listed in Table 16 shows average concentrations for Plan 1A to be 5.9% higher than for (the original) Plan 1, and average concentrations for Plan 1B to be 3.2% higher than for (the original) Plan 1. Since the conversion of 8% of the total land area from the research category to manufacturing within Plan 1 would cause an approximate increase in total regional SO_2 air quality in Plan 1 of 3.2%, the resultant air quality for Plan 1 thus would be within the same range of values as regional SO_2 air quality for Plans 1A and 1B, even though Plan 1 still retains 31% open space and only 6% residential area.

It is concluded from this simple example that open space is not a dominant influence on regional air quality concentration levels. Rather, regional air quality is far more sensitive to "heavy polluting" land use categories. A direct trade between manufacturing and open space land uses, however, would be highly beneficial to regional air quality levels, not because of the addition of open space within the land use plan, but rather because of the deletion of manufacturing land use categories.

Finally, it is to be noted that this analysis of the effects of open space says nothing about localized (microscale) impacts. It is highly probable that the presence of open space can have a significant effect on local pollutant levels, especially variations in concentrations over small distances and short time periods, which would not be observable at the regional scale of analysis.

6.3.2.6 Seasonal Variations

Seasonal variations in total air quality were investigated by calculating the summer (June-August) and winter (December-February) average concentrations for all five pollutants in each of the four alternative plans. These seasonal values were compared with the corresponding mean annual (12-month) concentrations.

The preparation of emissions data for the summer and winter cases is described in detail in the Task 1 Report. The meteorological data for the two seasons is described in the Task 2 Report. For reference, wind direction roses for the summer, winter and annual cases are illustrated in Figure 33. * These meteorological and emissions data were input to the MARTIK program and the resultant projected air quality concentrations within the Meadowlands were displayed by the by the SYMAP program. Computer-generated figures showing the isopleth contours of pollutant concentrations are given in Appendix B. Air quality contours for the annual case are illustrated in Figures B6 to B25, for the summer case in Figures B26 to B45, and for the winter case in Figures B46 to B65.

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*See page 150

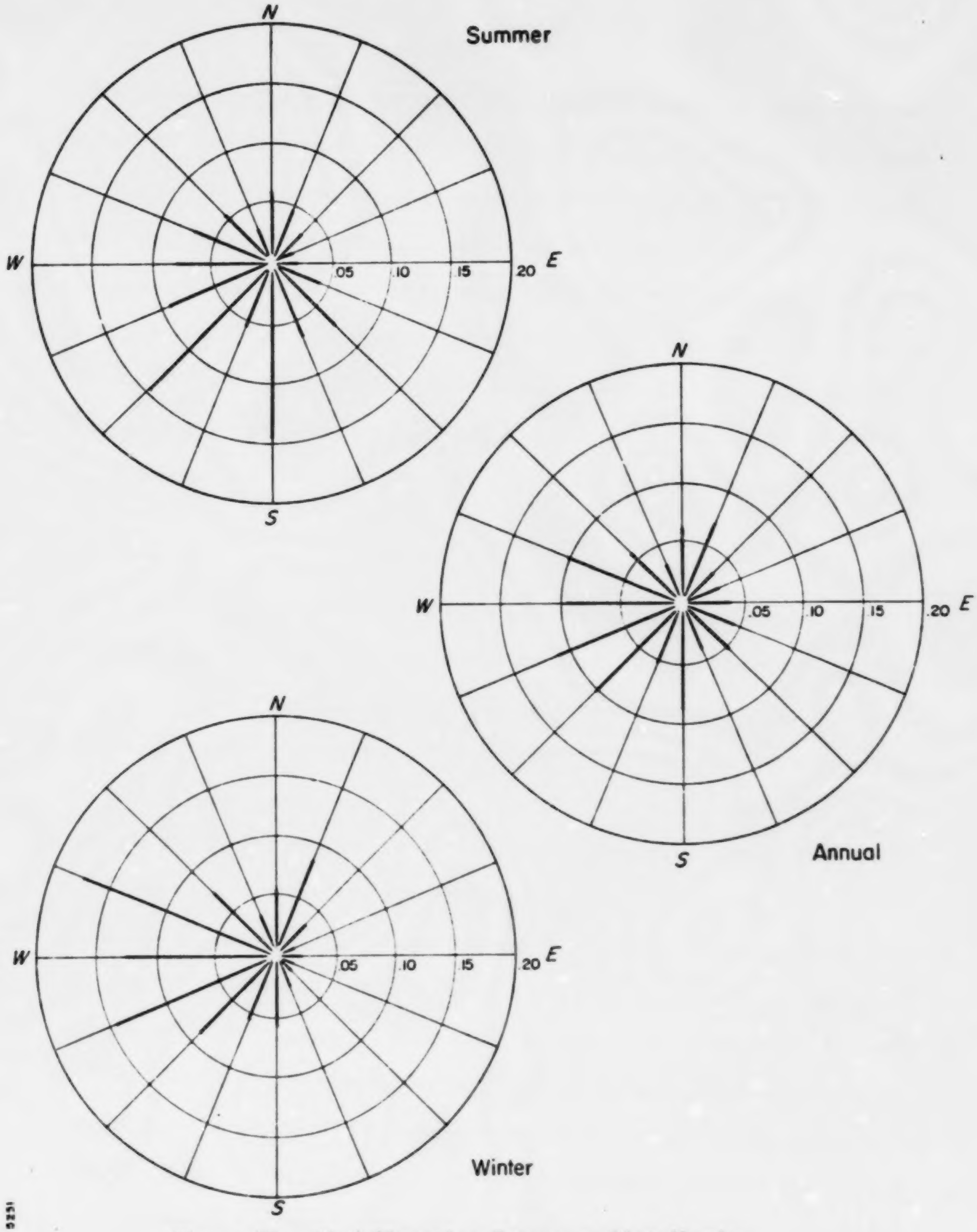

Figure 33 Wind Direction Frequency Distribution

The comparison of the annual, summer and winter cases shows a significant degree of variation in air quality contours for a given pollutant and a given plan. The corresponding comparison of the variation in air quality contours among different plans for a given pollutant and a given season shows that the characteristics of the seasonal contours are similar to those of the annual case. Moreover it is observed that the relative ranking of plans in terms of average regional air quality for a given pollutant is generally the same for the seasonal cases as for the annual case.

The pattern and degree of seasonal variation in air quality contours for a given pollutant and a given plan are illustrated by the calculation of the average total area exposure impact parameters (or equivalently the average regionwide pollutant concentration level). The results, shown in Table 19 for Plan 1 for all five pollutants, are representative of the seasonal variations for the other plans.

Seasonal variations are expected to occur as a result of the combined effect of differences in emission rates of the various pollutants with time of year and the differences in meteorological conditions prevailing. Because both the spatial variation in emission strength and the properties of emissions from elevated sources vs. low level sources is different for each pollutant, simple interpretations of the detailed seasonal variations predicted over the Meadowlands District are not possible. The results generally reflect the larger emission rates of pollutants and the generally poorer dispersion conditions associated with winter. The results for hydrocarbons levels show the reverse trend -- concentrations in the summer are slightly larger than those in the winter. This trend was also observed in the air quality measurements data collected near the Meadowlands and used for the model calibration (see Table 2-5 of the Task 2 Report).

TABLE 19

SEASONAL VARIATION IN AVERAGE CONCENTRATION LEVELS WITHIN THE HACKENSACK MEADOWLANDS FOR PLAN 1

Season	Pollutant									
	TSP		SO_2		CO		HC		NO_x	
	Avg Conc µg/m^3	Relative Ratio	Avg Conc pphm	Relative Ratio	Avg Conc ppm	Relative Ratio	Avg Conc µg/m^3	Relative Ratio	Avg Conc µg/m^3	Relative Ratio
Summer	85.3	1.00	0.83	1.00	0.36	1.00	1943	1.21	54.3	1.12
Annual	116.8	1.37	0.84	1.01	0.74	2.07	1607	1.00	48.4	1.00
Winter	127.8	1.49	1.08	1.29	1.56	4.34	1881	1.17	73.3	1.52

6.3.3 Impacts on Receptors

6.3.3.1 Principal Receptors of Interest

As discussed in Section 5.2.3 the receptors and land use categories of particular interest in this analysis include population, students, residential area, open space, and the combination of commercial and industrial area. As shown by the percent background levels in Table 6 the direct contribution of the source emissions from any particular land use plan represents only a small fraction of the contribution to total regional air quality. However, the impact of total regional air quality on specific receptors within a plan can be major, especially if the concentration levels associated with total air quality within the planning region are high.

The basic data for these receptors were retrieved from the coded land use data base by using the COMP 5 routine (as described in the Task 5 Report) of the LANTRAN program in the AQUIP System. In particular, information concerning the number of receptors (or alternatively the amount of land area associated with each land use category) within each grid cell within the planning region was retrieved and processed for use in the impact analysis.

These data were used primarily to correlate the specific number of receptors with pollutant concentration levels within each grid cell as necessary to calculate quantitative impact parameters. However, these data were also displayed graphically through use of the LANTRAN program to show the spatial distribution and densities by grid cell for each receptor or land use category of interest. These results are shown in Figures 34 to 52. (Since no schools were specified in the Plan 1C planning data, no plot of the spatial distribution of students is given.) These spatial patterns of receptor locations and land use densities were used in the visual correlation of air quality contours and receptor data. For example, Figures 34 to 37 show the spatial distributions of population density for the four plans. Similar plots are given for students, residential area, commercial and industrial area, and open space. (Open space land use was coded manually from the plan base maps for input to the LANTRAN program.)

6.3.3.2 Comparison of Plans by Pollutant

The visual correlation of air quality contours with land use categories and critical receptors provides a great deal of insight into both the impact of land use plans on air quality and the impact of regional air quality on specific receptors. It is found, however, that the basic results determined by the use of quantitative impact measures confirm the subjective conclusions derived from such visual evaluations of plans. As a consequence, the primary results of the analysis of the pollutant by pollutant impact of air quality on specific receptors and land use categories are reported in terms of quantitative measures of impact.

As discussed in Section 5.2.3 the quantitative measures of impact found to be most useful in the analysis of receptor impacts are integrated receptor exposures and average receptor exposures. These impact measures were calculated for each of the five basic receptors described in the previous

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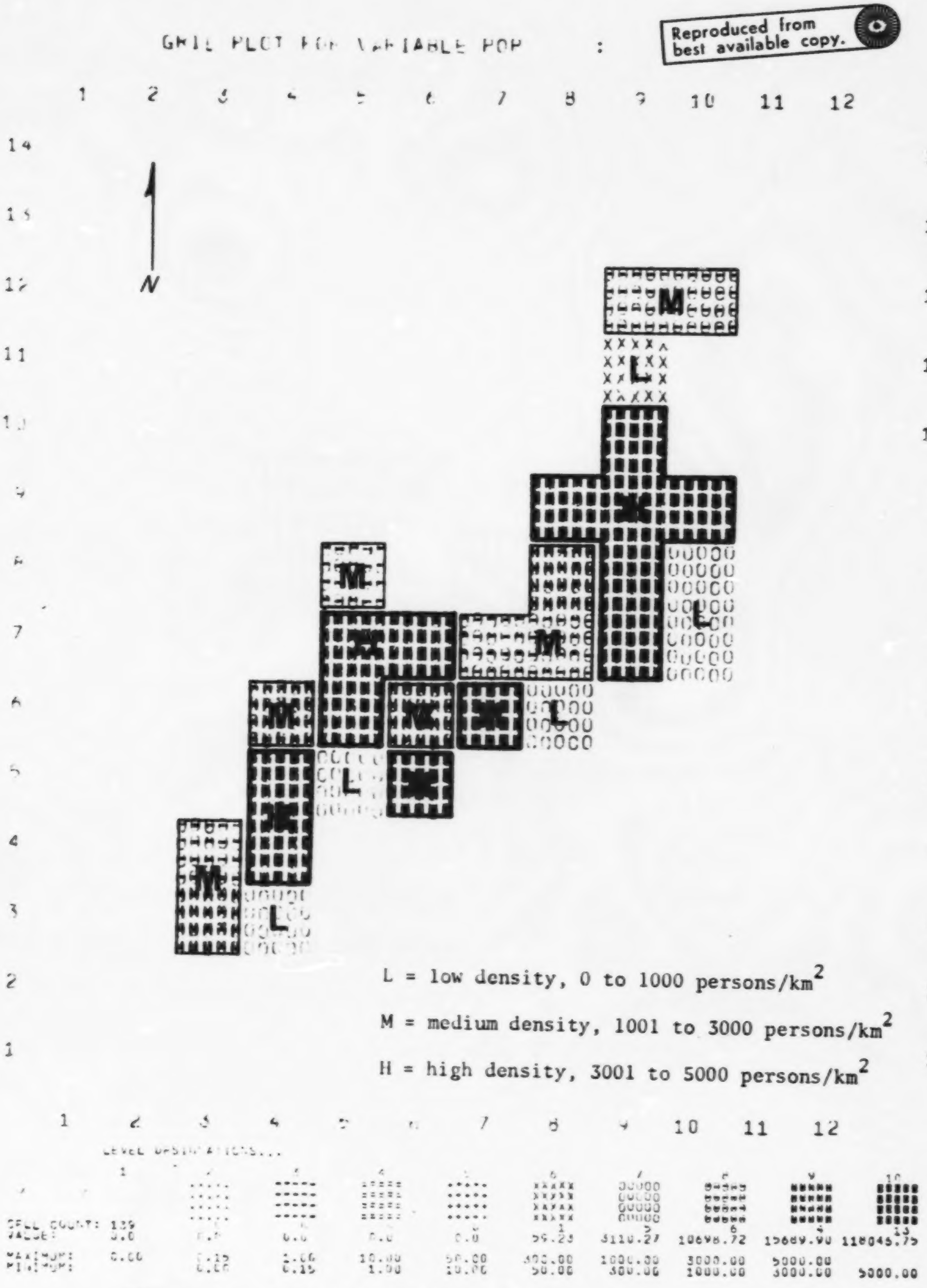

GRID PLOT FOR VARIABLE POP :
1 2 3 4 5 6 7 8 9 10 11 12
14 13 12 11 10 9 8 7 6 5 4 3 2 1
N
M
L
M
M
M
L
L
M
L
M
L
LEVEL DESIGNATIONS...
1 2 3 4 5 6 7 8 9 10
CELL COUNT: 139 1 5 6 4 13
VALUE: 0.0 0.0 0.0 0.0 0.0 59.23 3110.27 10698.72 15689.90 118045.75
MAXIMUM: 0.00 0.15 1.00 10.00 50.00 300.00 1000.00 3000.00 5000.00
MINIMUM: 0.00 0.15 1.00 10.00 50.00 300.00 1000.00 3000.00 5000.00

L = low density, 0 to 1000 persons/km^2

M = medium density, 1001 to 3000 persons/km^2

H = high density, 3001 to 5000 persons/km^2

Figure 34 Grid Plot for Population Density for Plan 1

6446

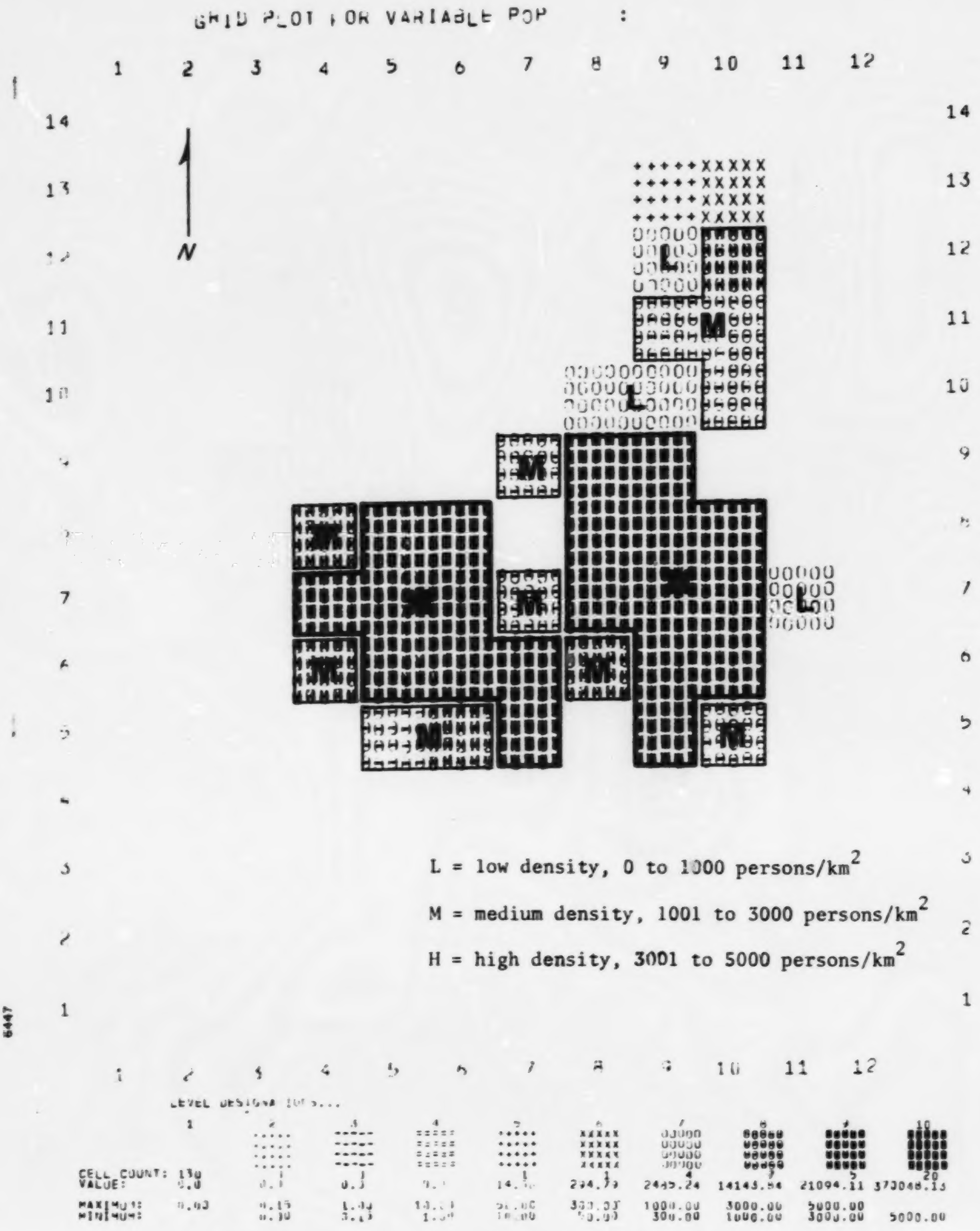

GRID PLOT FOR VARIABLE POP :
N
L
M
L = low density, 0 to 1000 persons/km²
M = medium density, 1001 to 3000 persons/km²
H = high density, 3001 to 5000 persons/km²
LEVEL DESIGNATIONS...
CELL COUNT:
VALUE:
MAXIMUM:
MINIMUM:

Figure 35 Grid Plot for Population Density for Plan 1A

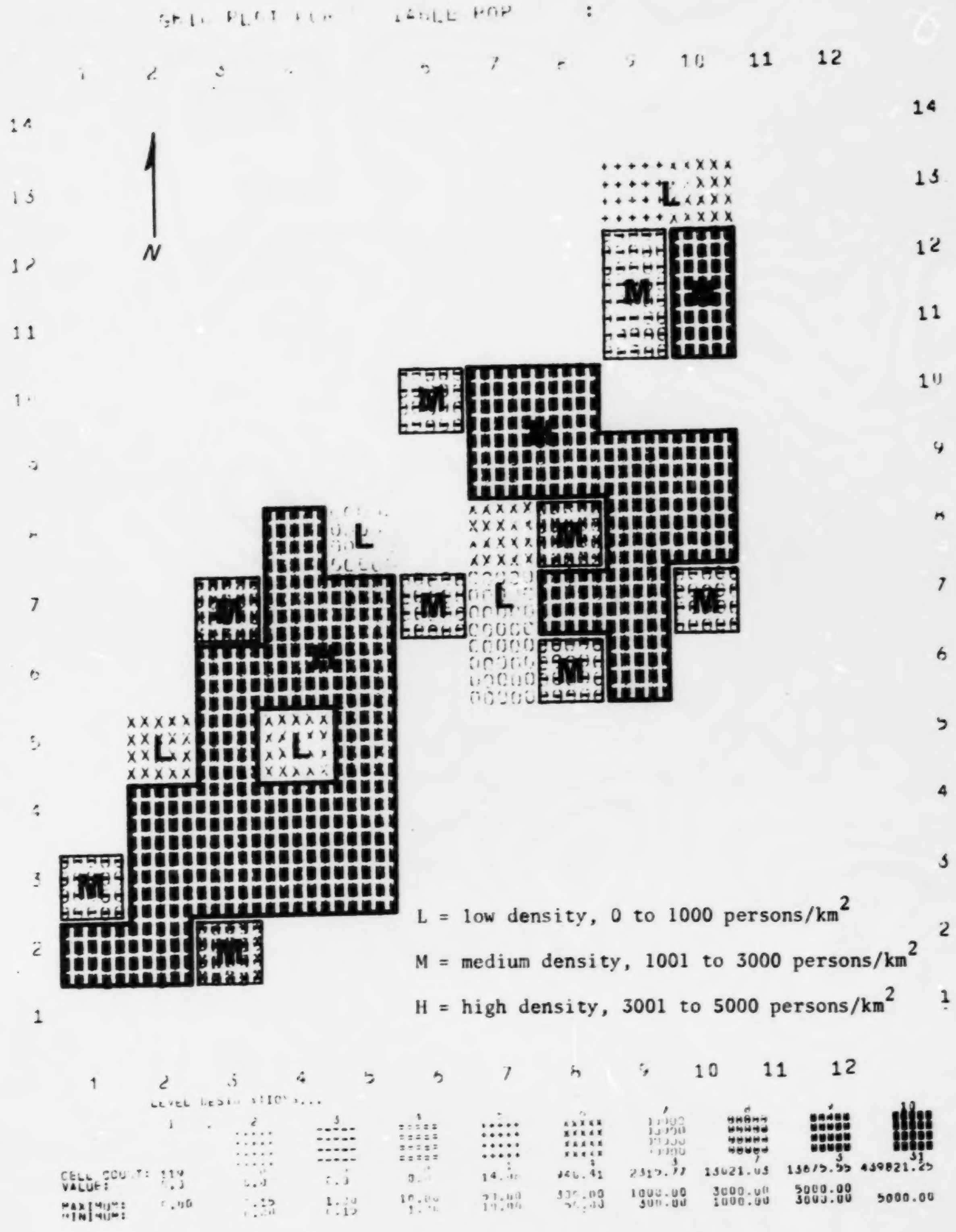
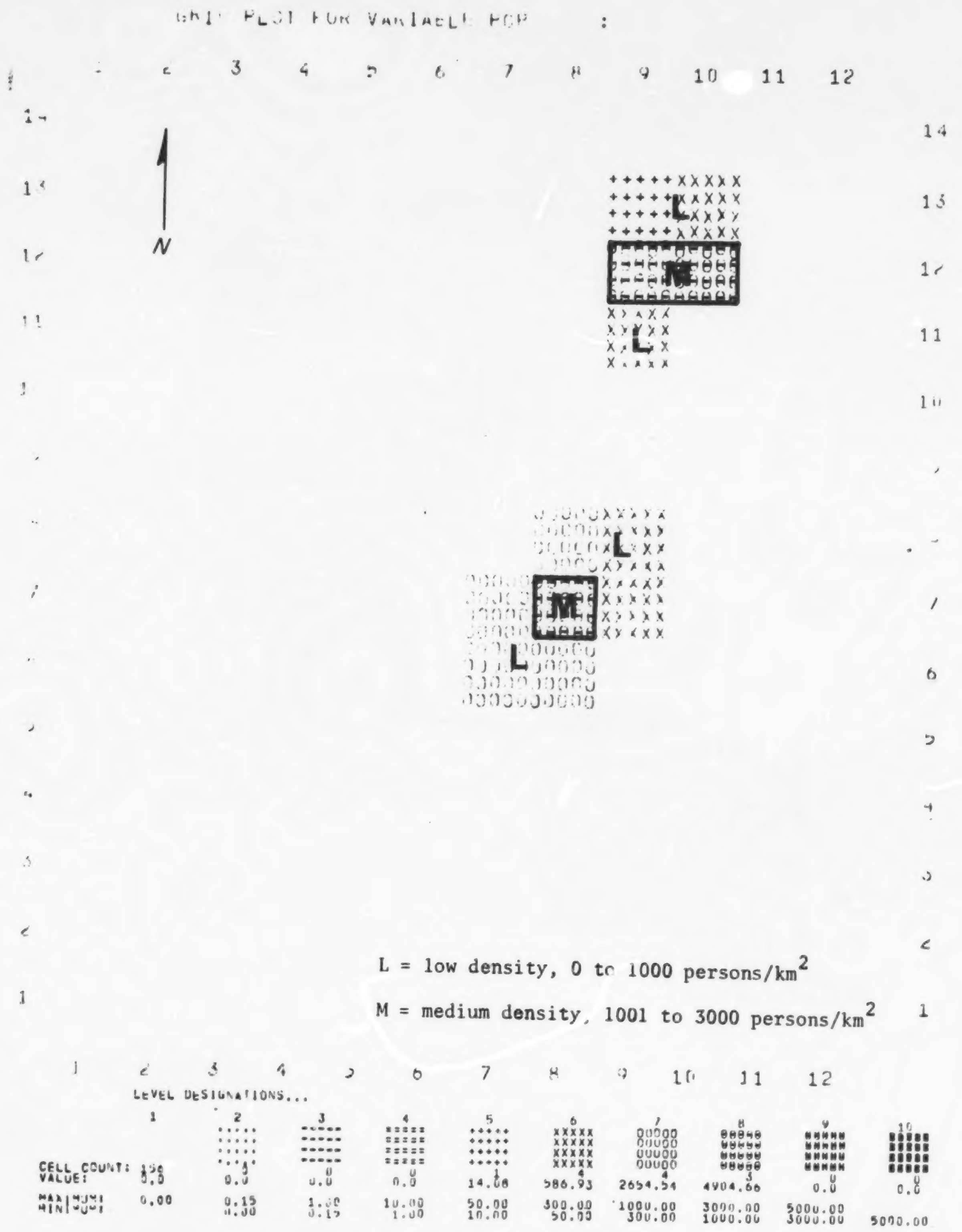


TABLE POP
N
L
M
H
L = low density, 0 to 1000 persons/km2
M = medium density, 1001 to 3000 persons/km2
H = high density, 3001 to 5000 persons/km2
1
2
3
4
5
6
7
8
9
10
11
12
13
14
CELL COUNT:
VALUE:
MAXIMUM:
MINIMUM:
13621.03
13675.55
439821.25
1000.00
500.00
3000.00
1000.00
5000.00
3000.00
5000.00

Figure 36 Grid Plot for Population Density for Plan 1B



```
GRID PLOT FOR VARIABLE POP      :
```

L = low density, 0 to 1000 persons/km^2

M = medium density, 1001 to 3000 persons/km^2

```
LEVEL DESIGNATIONS...
              1        2        3        4        5        6        7        8        9       10
                     .....    -----    =====    +++++    XXXXX    00000    88888    #####    █████
                     .....    -----    =====    +++++    XXXXX    00000    88888    #####    █████
                     .....    -----    =====    +++++    XXXXX    00000    88888    #####    █████
                     .....    -----    =====    +++++    XXXXX    00000    88888    #####    █████
CELL COUNT:  156       3        0        0        1        4        4        3        0        0
VALUE:       0.0      0.0      0.0      0.0    14.08   586.93  2654.54  4904.66     0.0      0.0

MAXIMUM:     0.00     0.15     1.00    10.00    50.00   300.00  1000.00  3000.00  5000.00
MINIMUM:              0.00     0.15     1.00    10.00    50.00   300.00  1000.00  3000.00  5000.00
```

Figure 37 Grid Plot for Population Density for Plan 1C

6449

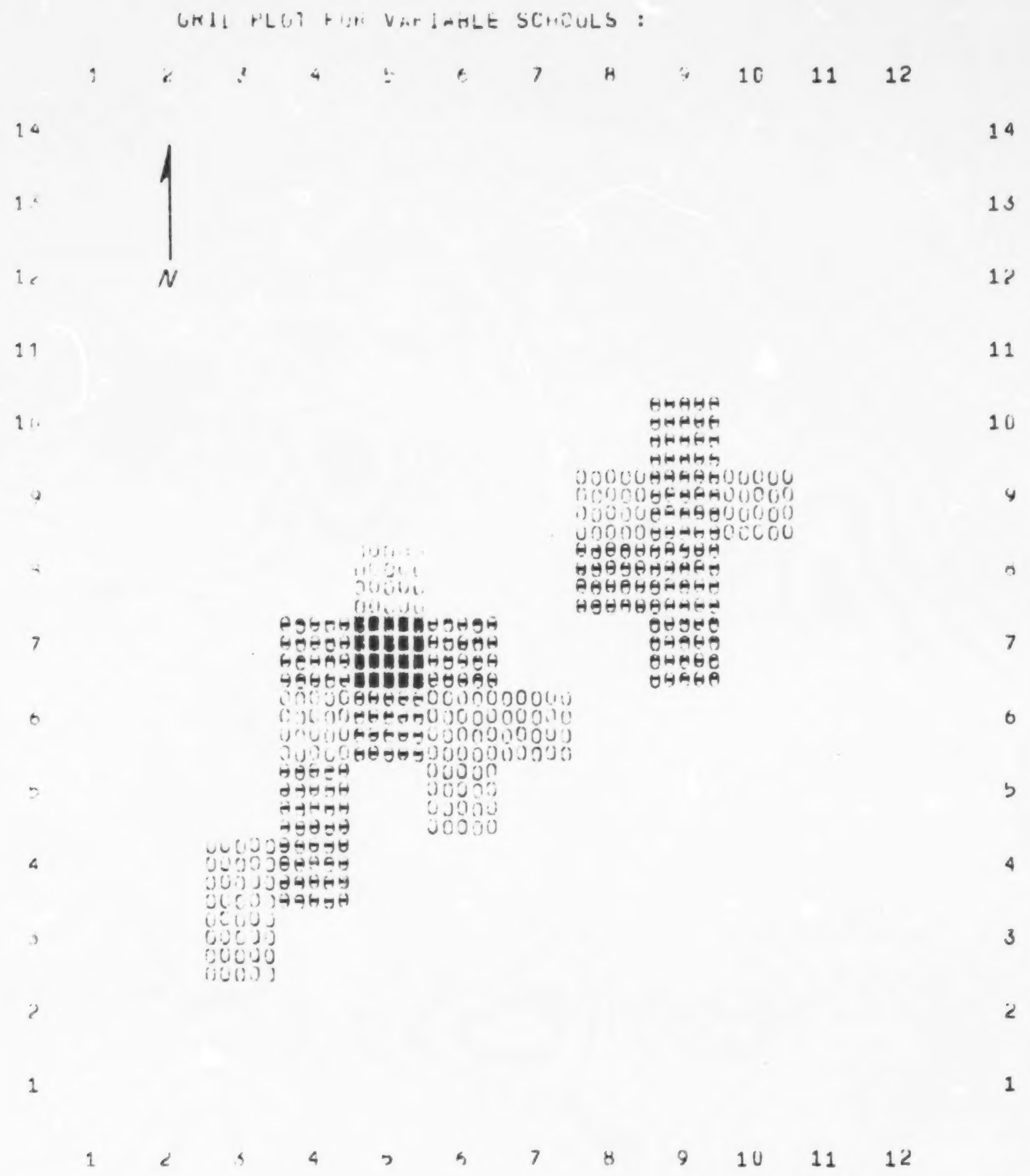

GRID PLOT FOR VARIABLE SCHOOLS :
1 2 3 4 5 6 7 8 9 10 11 12
14 13 12 11 10 9 8 7 6 5 4 3 2 1
N

Figure 38 Grid Plot for Student Density for Plan 1

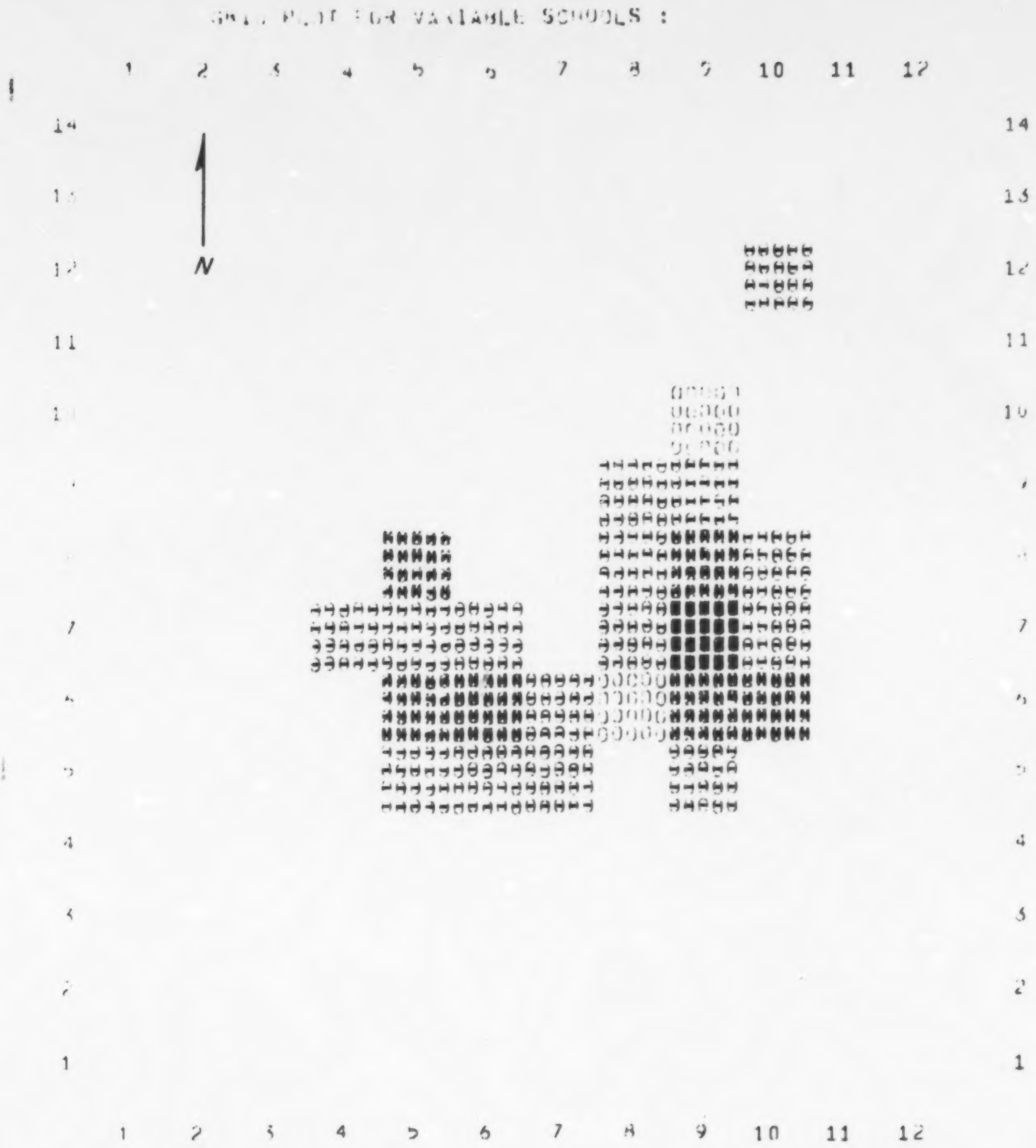
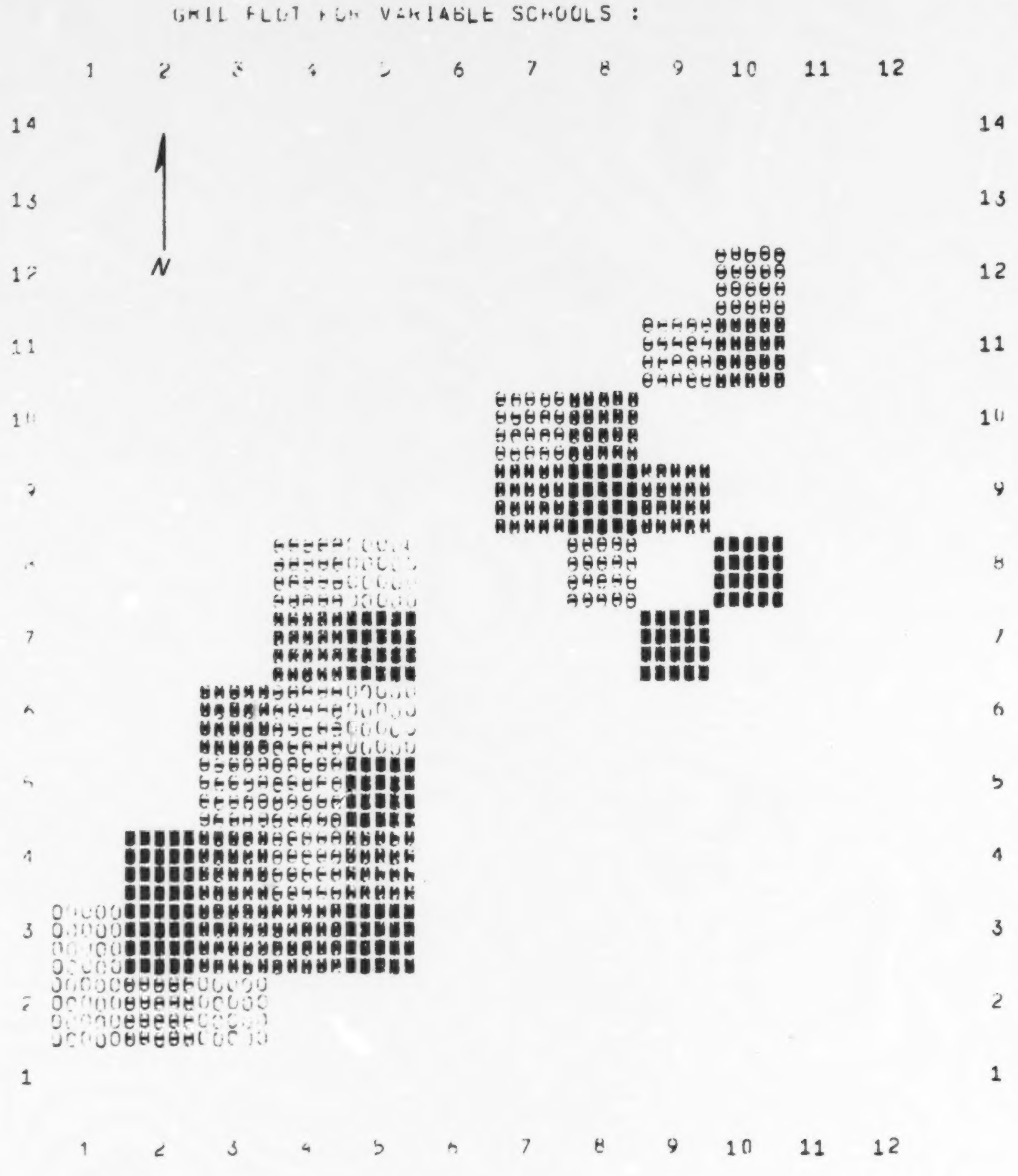


Figure 39 Grid Plot for Student Density for Plan 1A



GRID PLOT FOR VARIABLE SCHOOLS :
1
2
3
4
5
6
7
8
9
10
11
12
14
13
12
11
10
9
8
7
6
5
4
3
2
1
N

Figure 40 Grid Plot for Student Density for Plan 1B

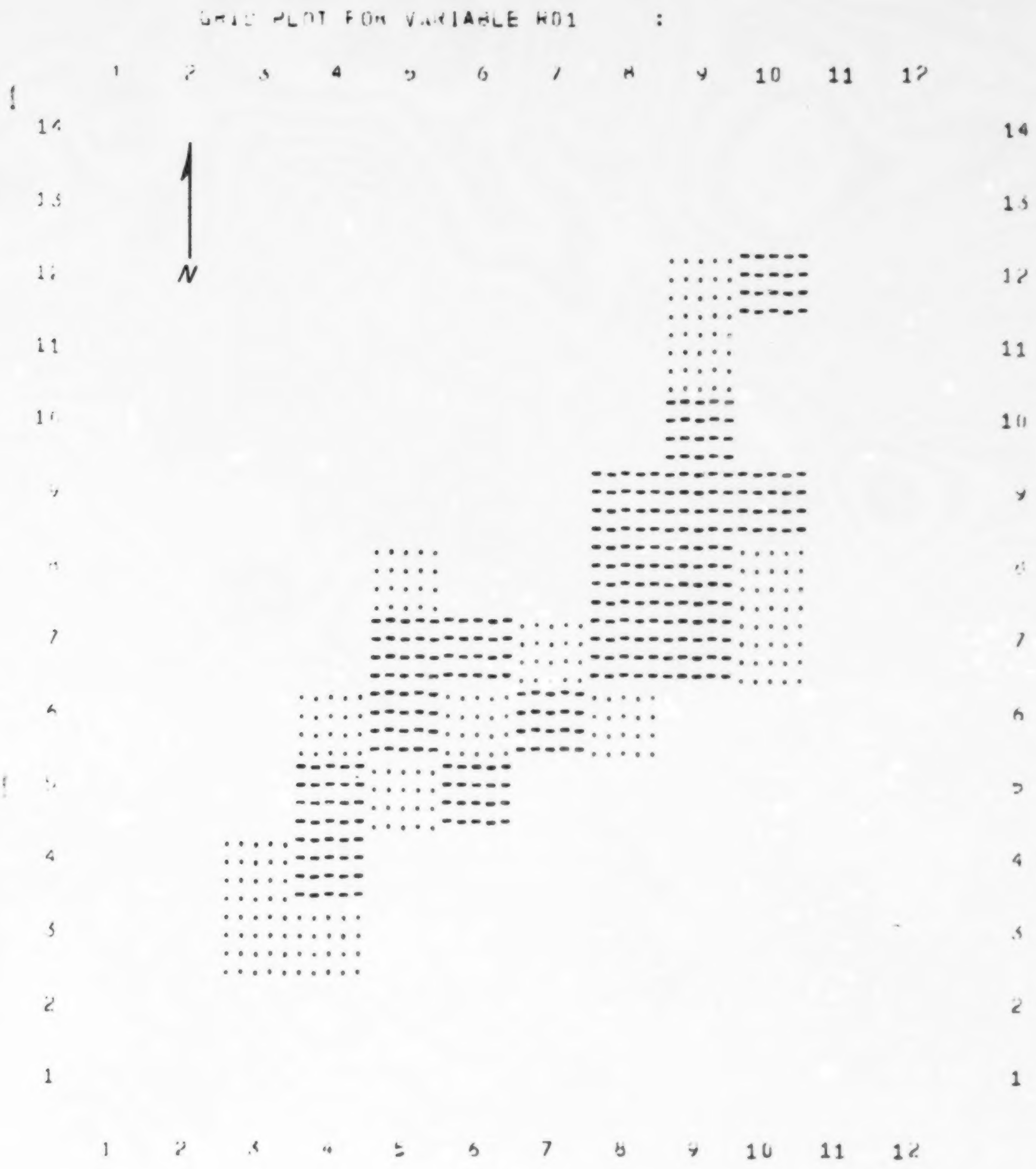


Figure 41 Grid Plot for Residential Area Density for Plan 1

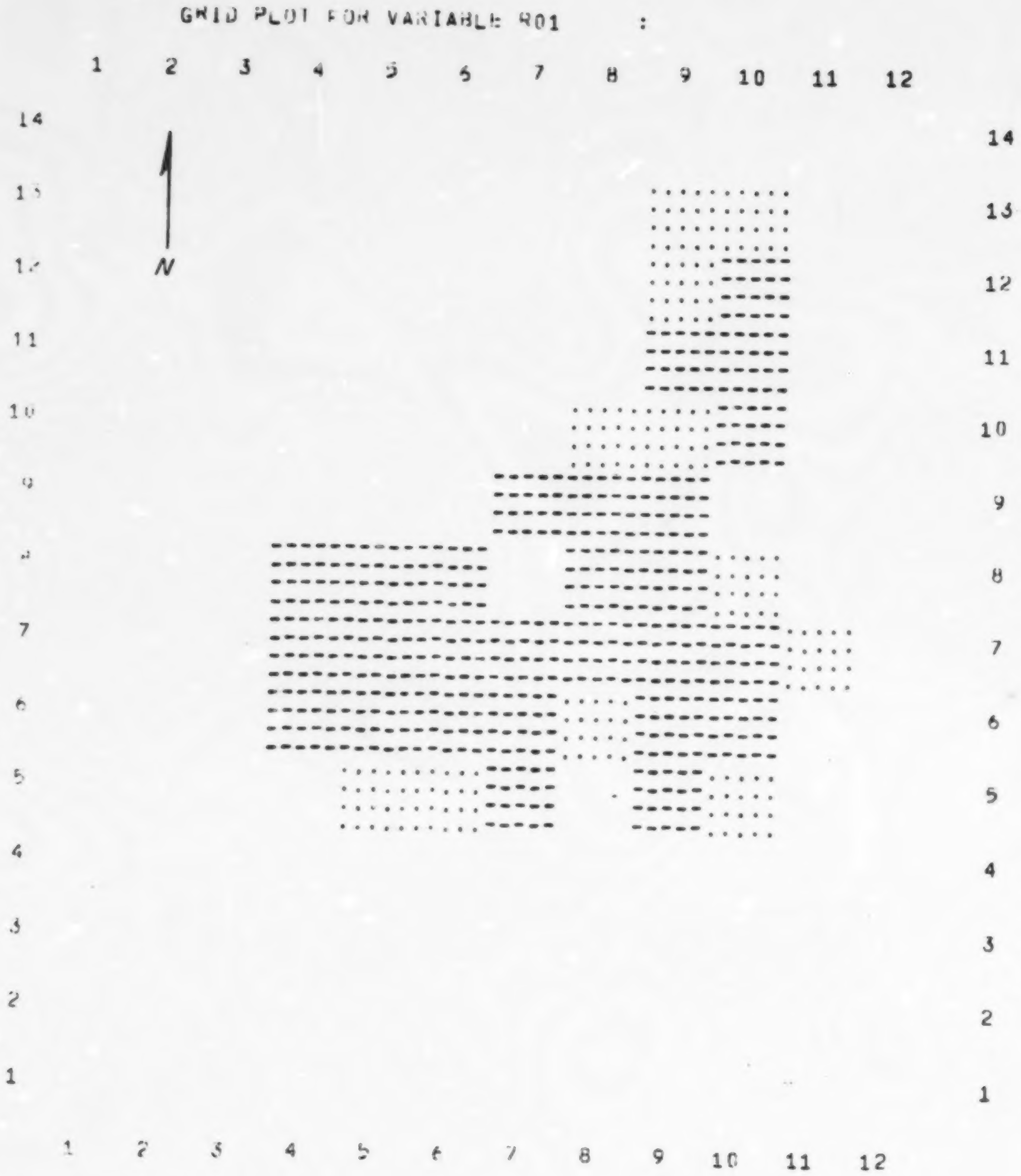

GRID PLOT FOR VARIABLE R01 :
1 2 3 4 5 6 7 8 9 10 11 12
14 13 12 11 10 9 8 7 6 5 4 3 2 1
N

Figure 42 Grid Plot for Residential Area Density for Plan 1A

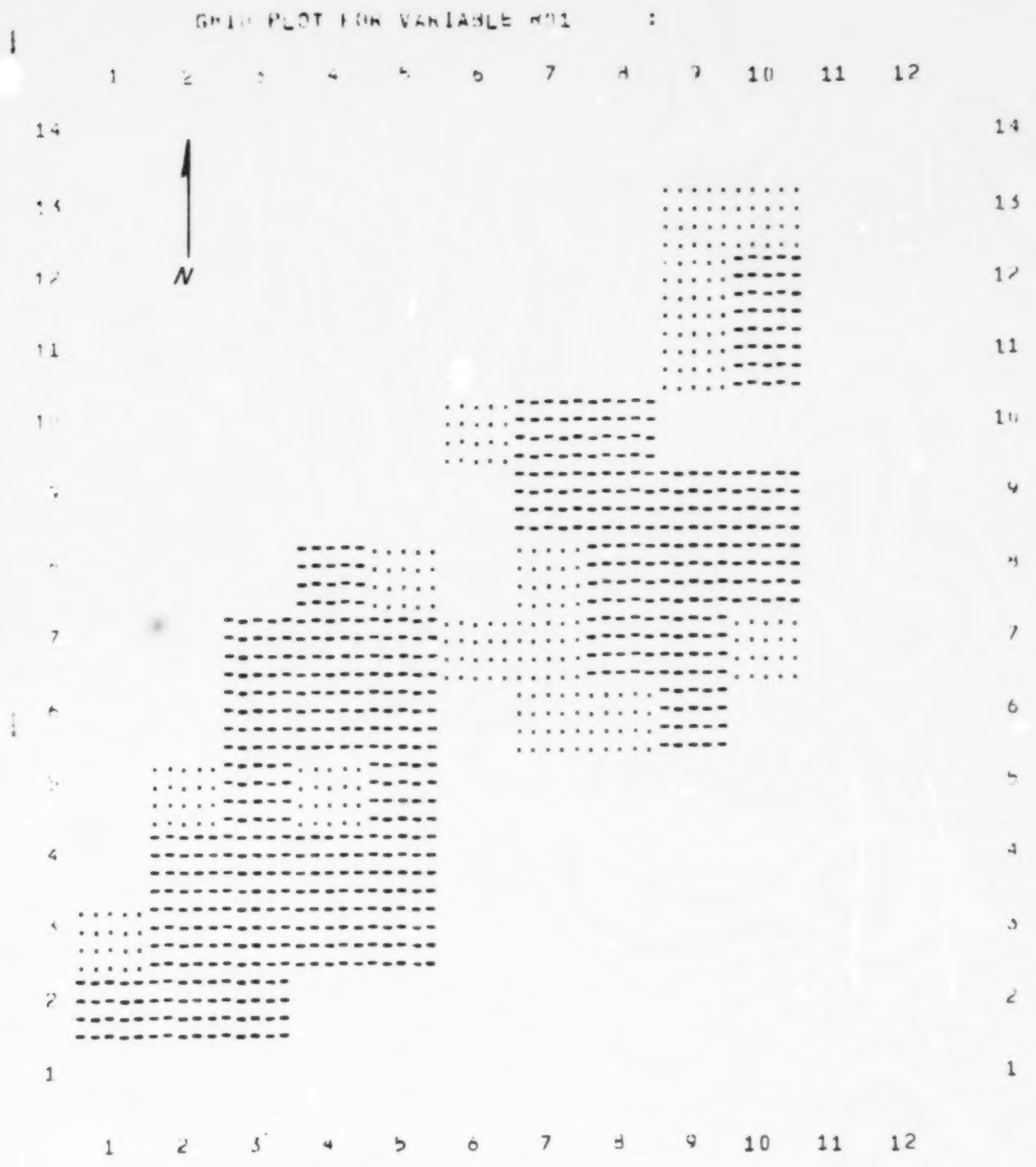

GRID PLOT FOR VARIABLE R01 :
1 2 3 4 5 6 7 8 9 10 11 12
14
13
12
11
10
9
8
7
6
5
4
3
2
1
N

Figure 43 Grid Plot for Residential Area Density for Plan 1B

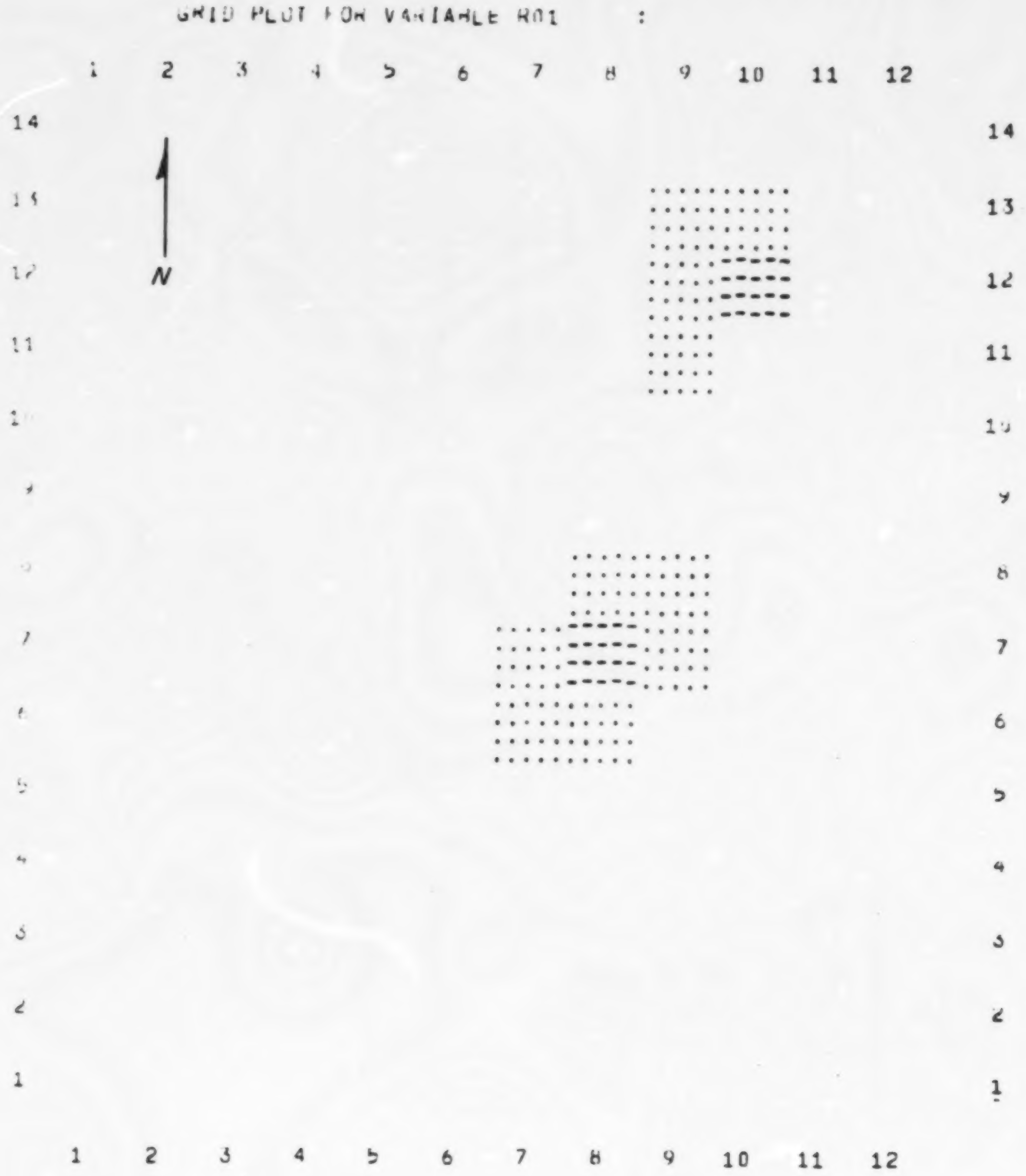

GRID PLOT FOR VARIABLE R01 :
1 2 3 4 5 6 7 8 9 10 11 12
14 13 12 11 10 9 8 7 6 5 4 3 2 1
N

Figure 44 Grid Plot for Residential Area Density for Plan 1C

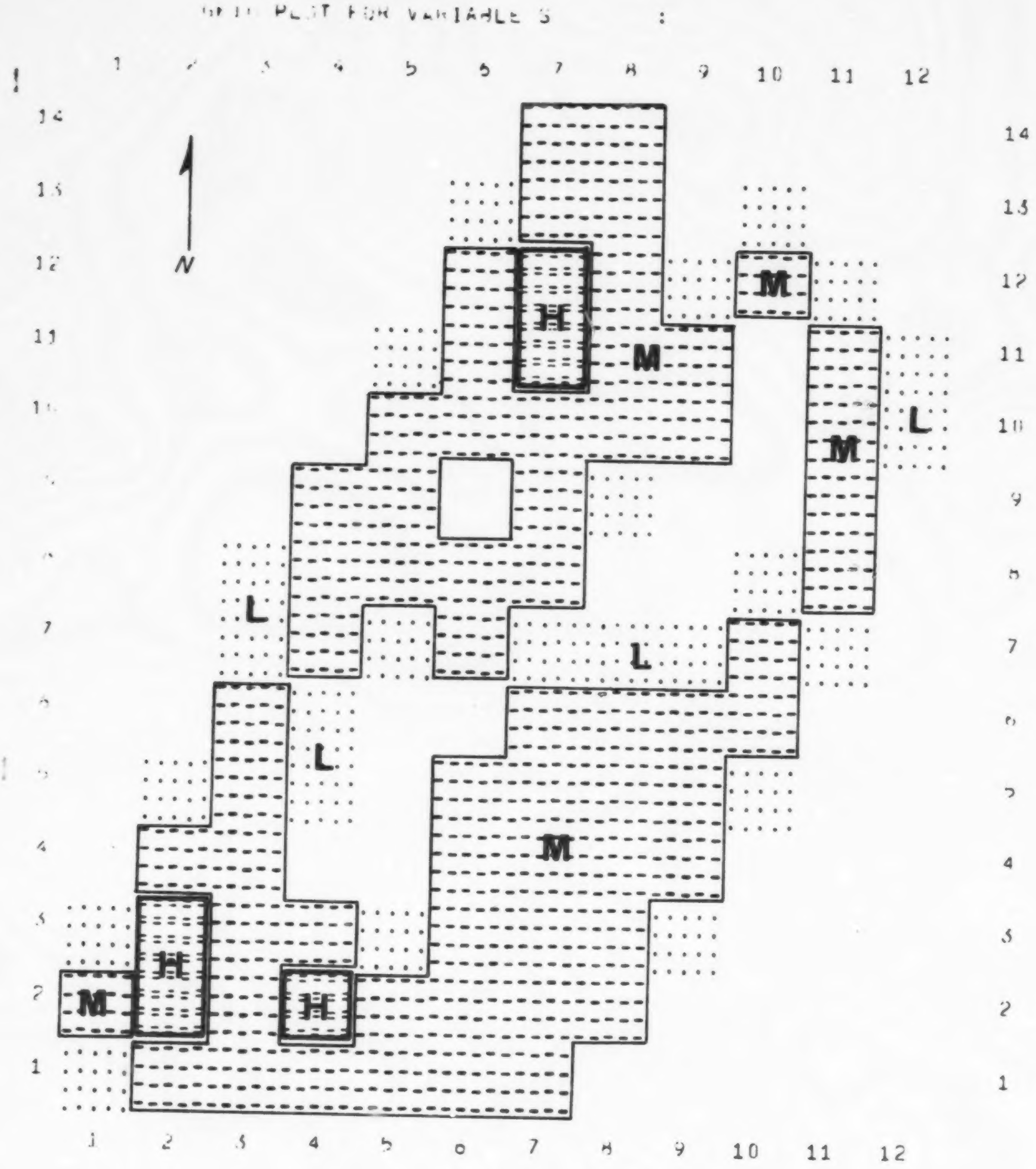

GRID PLOT FOR VARIABLE 5 :
1
2
3
4
5
6
7
8
9
10
11
12
14
13
12
11
10
9
8
7
6
5
4
3
2
1
N
H
M
M
M
L
L
L
L
M
H
H
M

Figure 45 Grid Plot for Commercial and Industrial Land Use Density for Plan 1

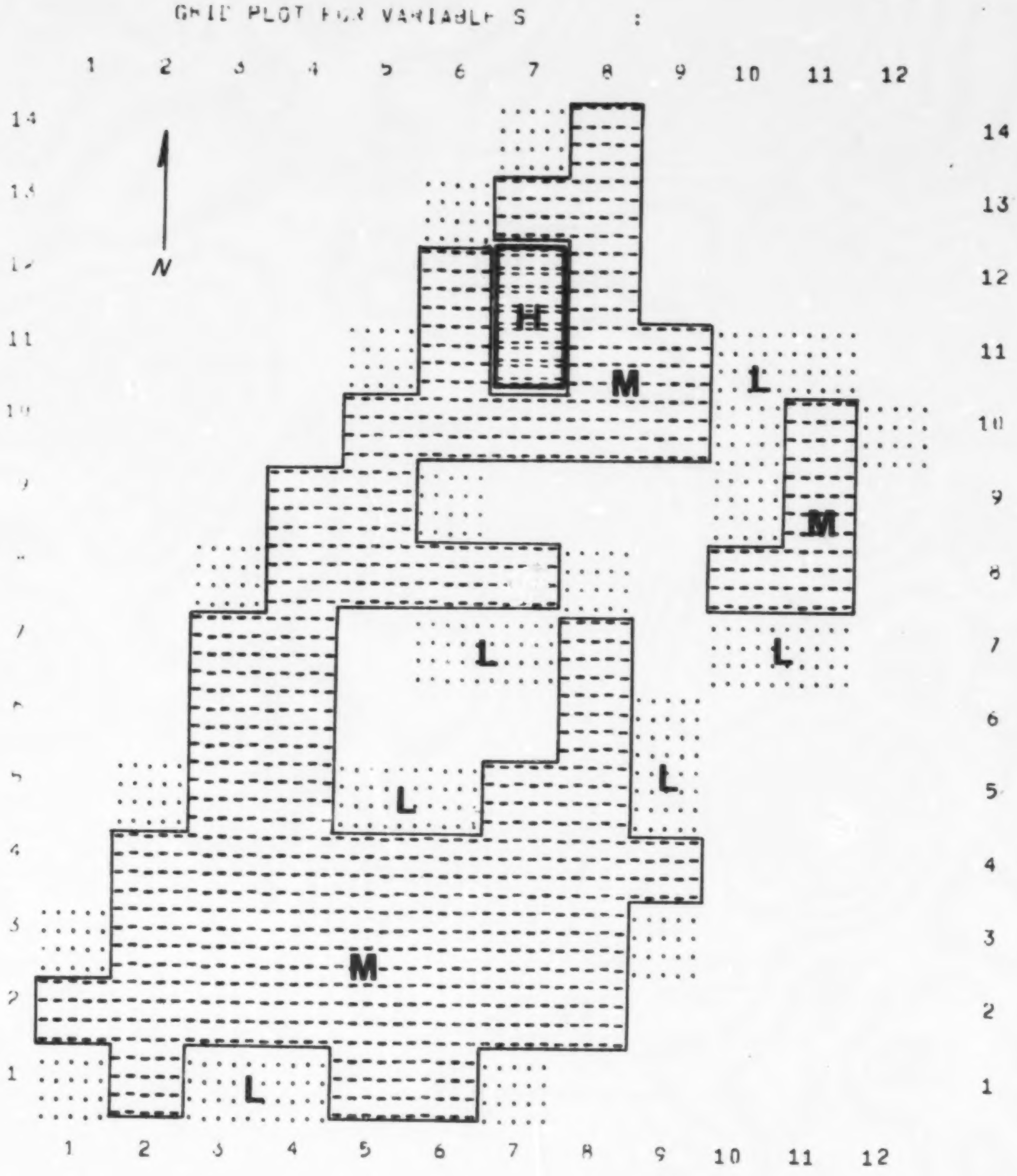

GRID PLOT FOR VARIABLE S :
1 2 3 4 5 6 7 8 9 10 11 12
14
13
12
11
10
9
8
7
6
5
4
3
2
1
N
H
M
L
M
L
L
L
L
M
L

Figure 46 Grid Plot for Commercial and Industrial Land Use Density for Plan 1A

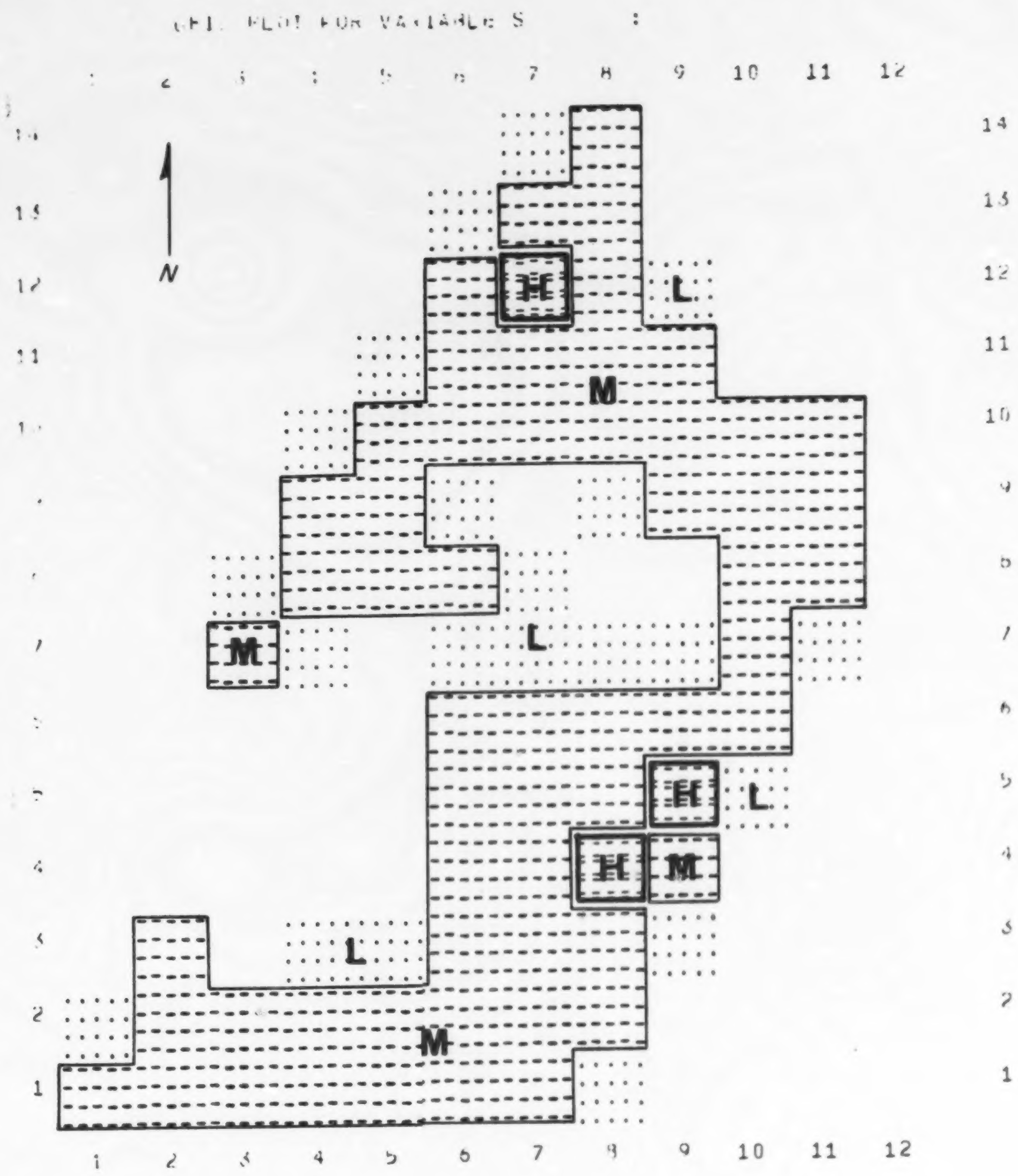

GRID PLOT FOR VARIABLE S
1 2 3 4 5 6 7 8 9 10 11 12
14 13 12 11 10 9 8 7 6 5 4 3 2 1
N
H
L
M
M
L
H
L
H
M
L
M

Figure 47 Grid Plot for Commercial and Institutional Land Use Density for Plan 1B

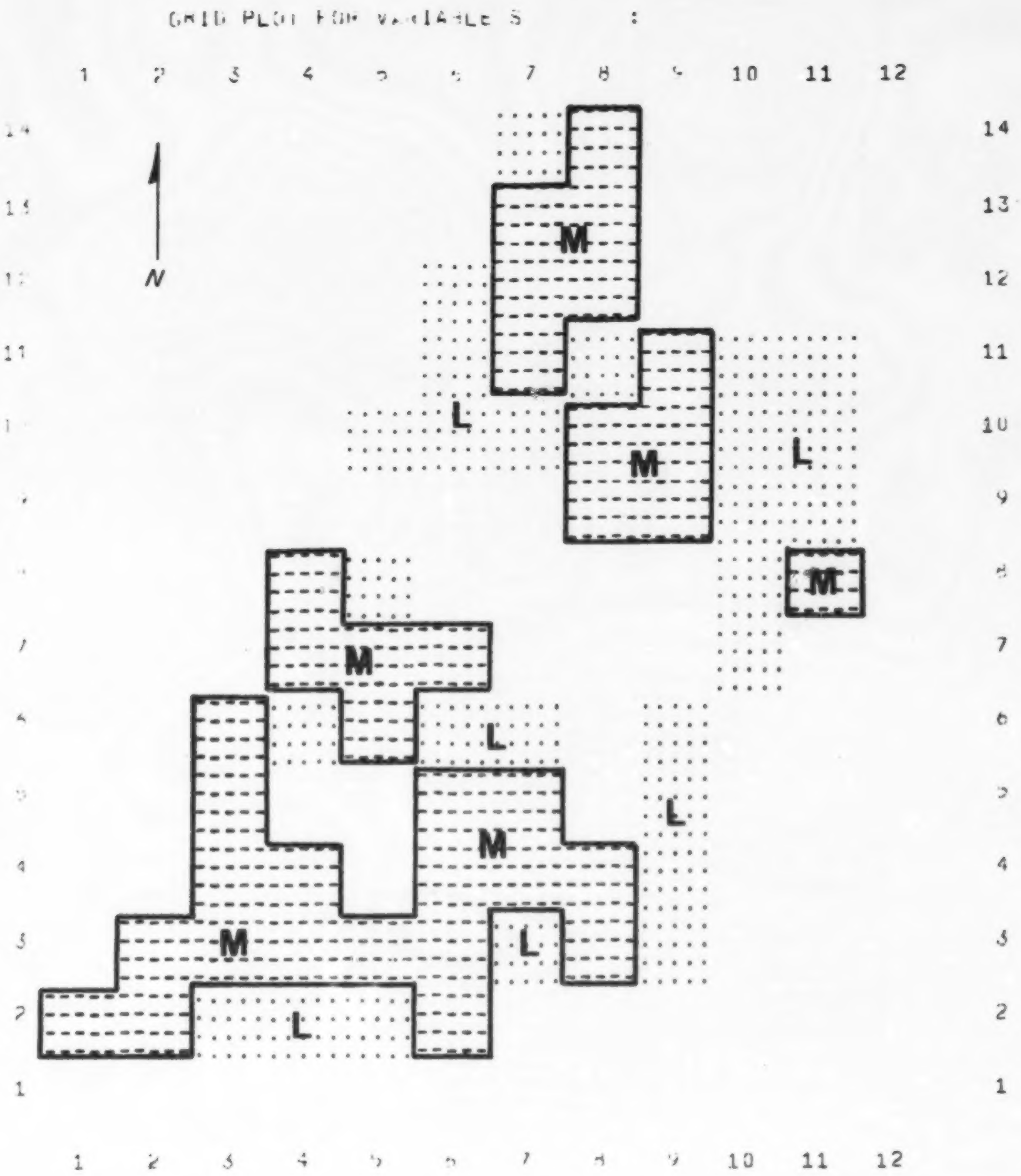


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Figure 48 Grid Plot for Commercial and Industrial Land Use Density for Plan 1C

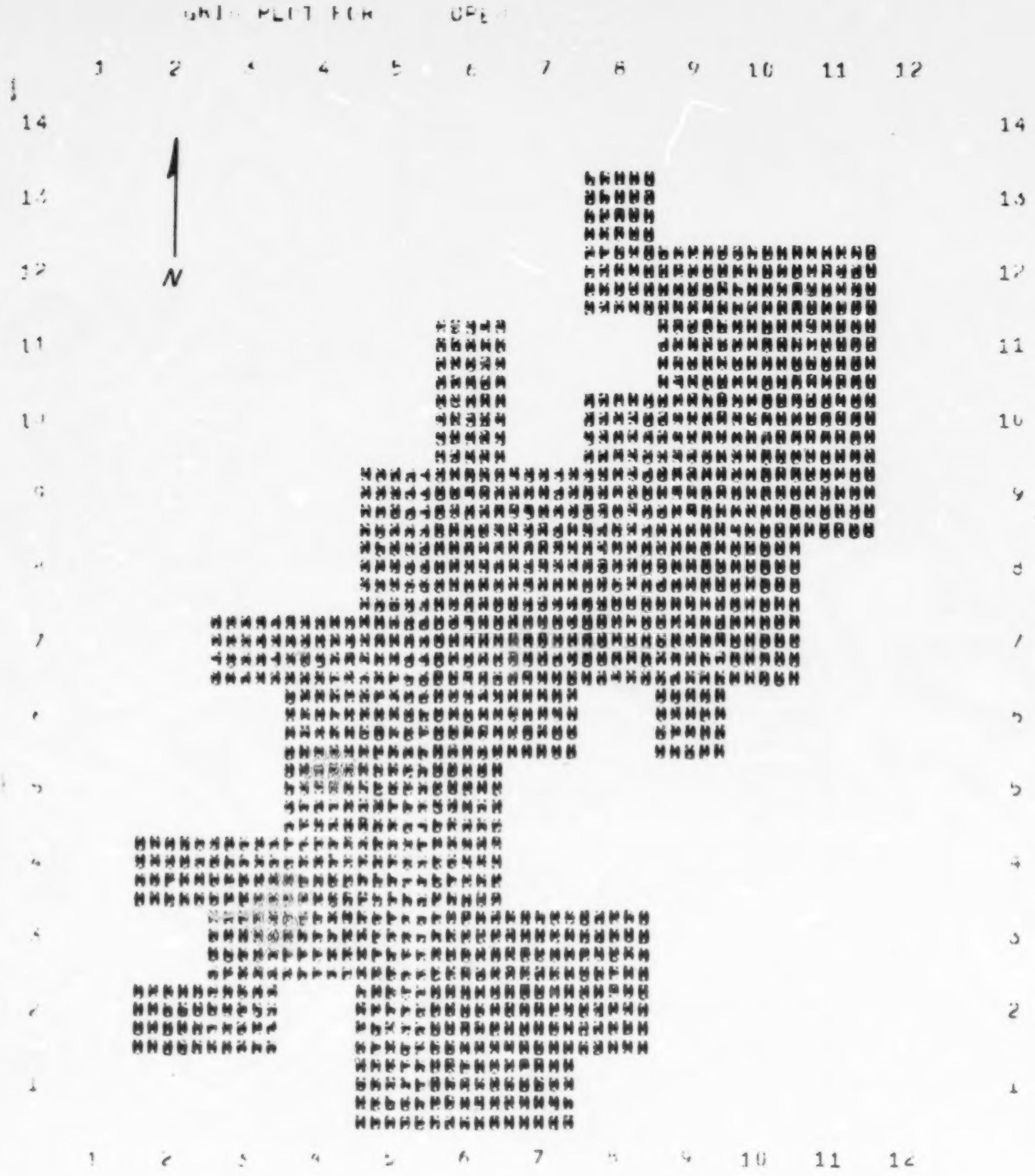
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Figure 49 Grid Plot for Open Space in Plan 1

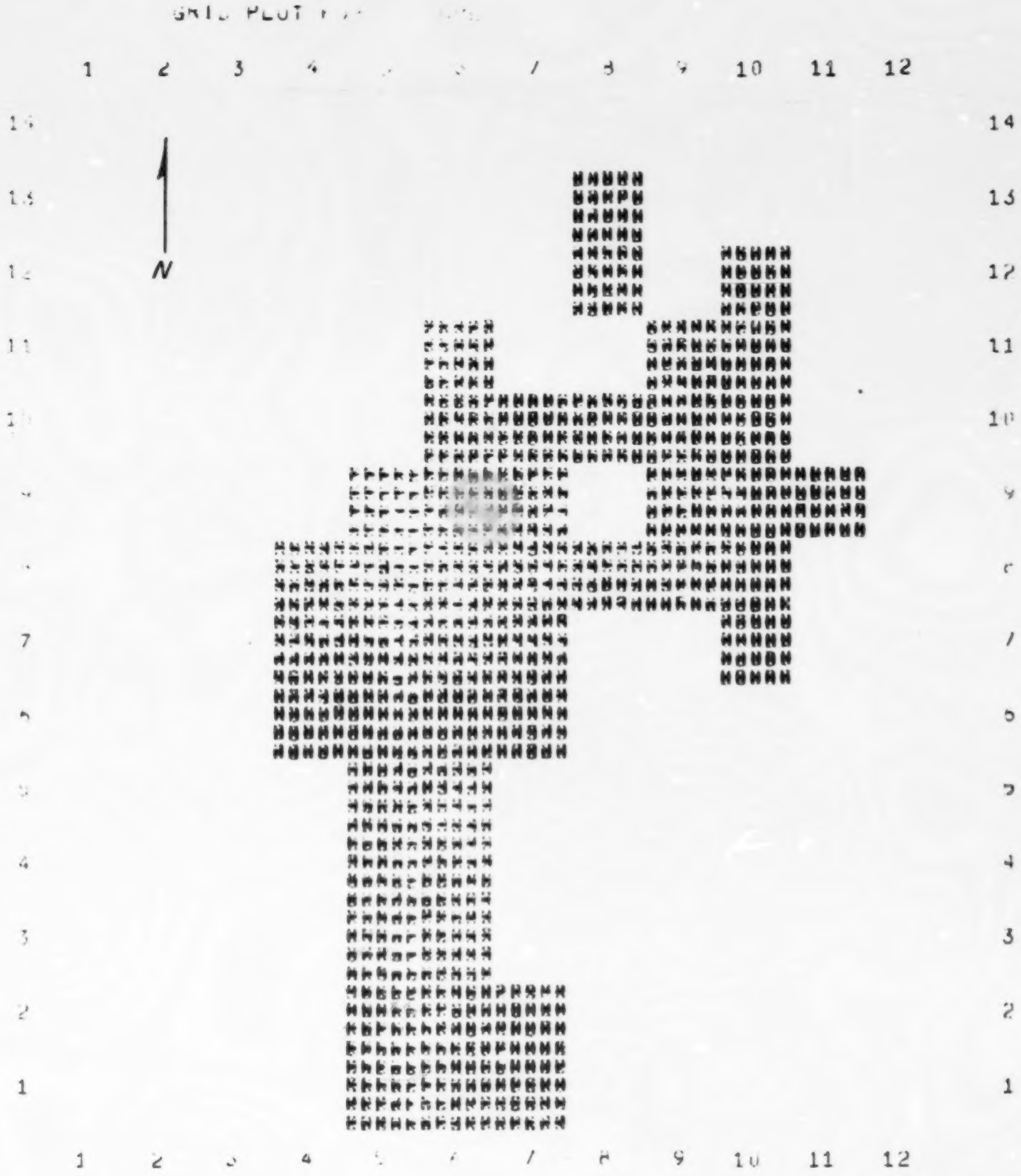
GRID PLOT
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Figure 50 Grid Plot for Open Space in Plan 1A

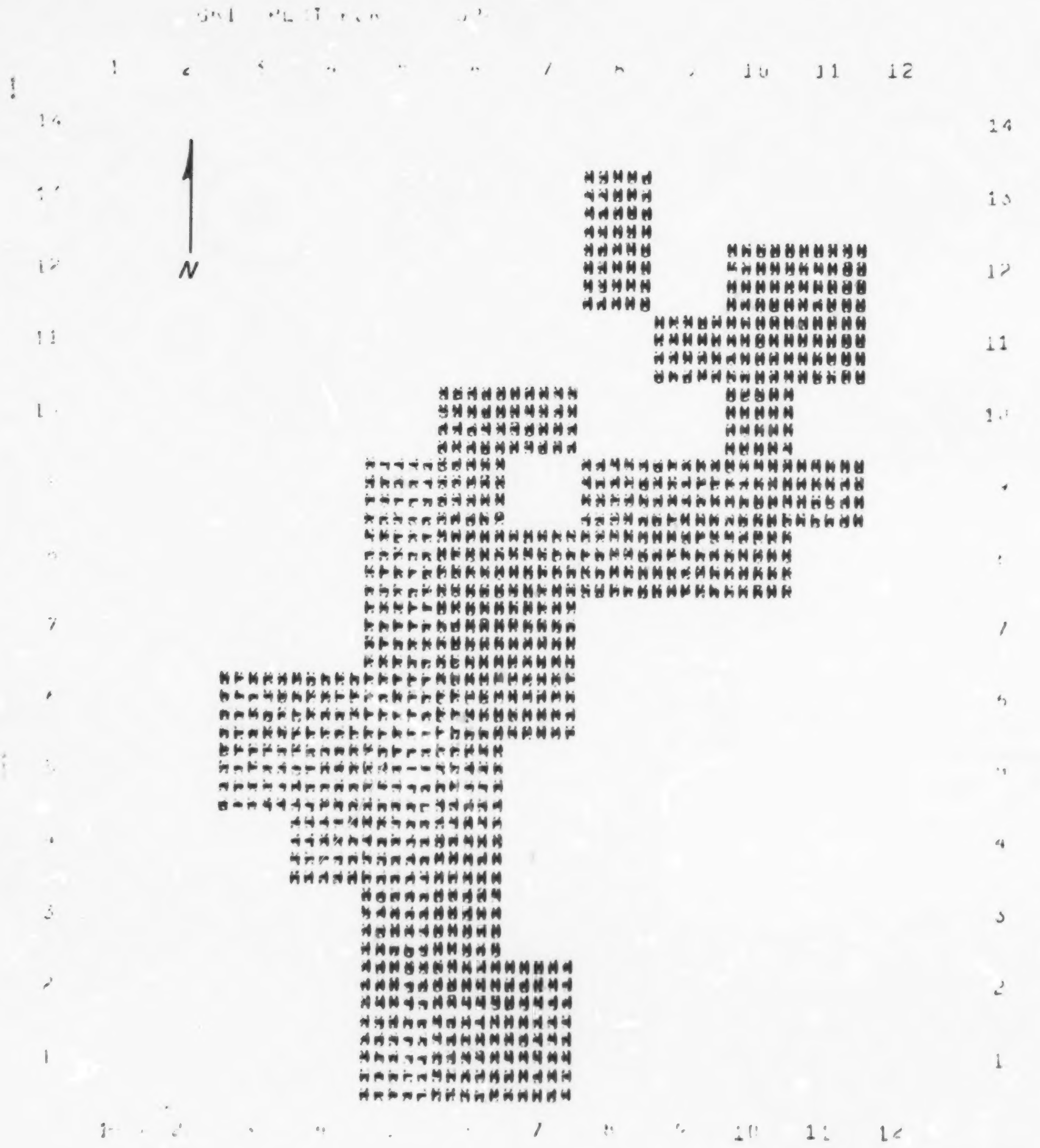
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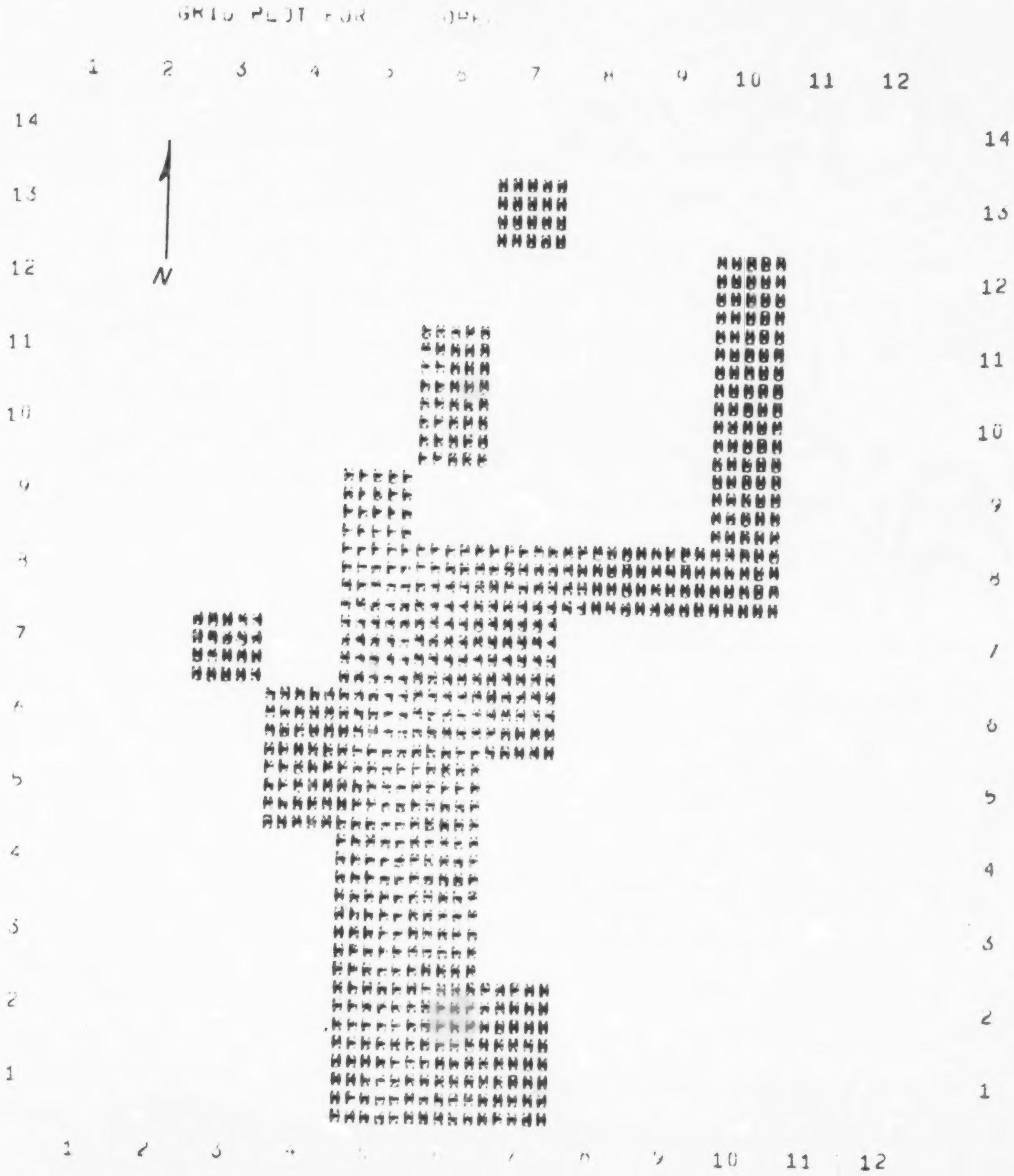
Figure 51   Grid Plot for Open Space in Plan 1B


GRID PLOT FOR OPEN
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14 13 12 11 10 9 8 7 6 5 4 3 2 1
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Figure 52 Grid Plot for Open Space in Plan 1C

section using the IMPACT program of the AQUIP System. In particular, the LANTRAN program was used to retrieve both the land use data for each receptor and the air quality concentration data for each pollutant, and to format the data on a gridded basis for input to IMPACT. These basic input data were used with a routine written in terms of the hyperlanguage of the IMPACT program to compute the impact parameter formula discussed in Section 5.2.3. The results of the calculations of the impact measure for each pollutant, for each plan and for each receptor are listed in Table 13 for integrated receptor exposure impact parameters and in Table 14 for average receptor exposure impact measures.

As was done in the case of the analysis of regional air quality, these impact measures were used to form the relative ratios among the calculated impact measures for each plan for a given pollutant. Such relative ratios are listed in Table 15 for integrated exposure measures and in Table 16 for average exposure impact parameters.

These relative ratios show the percent variation among the four plans in the impact on a specified receptor due to a given pollutant. They also form a basis for ranking the impact among the plans for a single pollutant. A summary of the ranking of plans on this pollutant by pollutant basis is given in Table 17 for each receptor.

The analysis of receptor impacts is illustrated by the results of the evaluation of the alternative plans in terms of impact on population. This special interest in population is based on a concern for the adverse effects of pollutants on the health of the general population and further motivated by the fact that the Federal primary ambient air quality standards were developed to protect public health. The ranking of plans based on the integrated population exposure impact measure clearly goes according to the level of population within each plan and is the same for all pollutants. Plan 1C is shown to be best (having least total population) followed by Plans 1, 1A and 1B. This impact measure reflects the fact that the total impact on receptors within a plan increases with the number of receptors (i.e., people) as well as with the level of concentration to which the receptors are exposed. It is also observed that the relative differences in pollutant concentrations among the plans are too small (because of the high background levels) to overcome the relative differences among plans due to population levels.

By contrast, the ranking of the plans for the average population exposure impact measure shows that the ranking order depends upon which pollutant is considered. For example, the ranking of the plans is similar for particulates, SO_2 and NO_X. Plan 1 is best, followed by Plans 1B, 1A, and 1C. Since this impact measure represents the average concentration to which any person within the populated area is exposed, it is noted that Plan 1 ranks best primarily due to its low regional concentration levels. On the other hand, Plan 1B ranks better than Plan 1A due to the relative location of populated regions within the plan. The population in Plan 1B is predominantly located within the western regions of the Meadowlands where concentrations generally are lowest, while Plan 1A has a significant amount of population located in the eastern portions of the Meadowlands where concentration levels generally are much higher. Although percent mix of land use categories in Plans 1B and 1A is very similar, the quantitative ranking in Table 17 shows that the impact on population can vary by as much as 8%, depending upon the pollutant.

The ranking of the plans in terms of average population exposure to CO shows that Plan 1 remains best, but is followed by Plans 1C, 1B, and 1A.

This shift in relative rank of Plan 1C (from fourth to second) reflects the fact that regional CO levels in Plan 1C are significantly lower than those in Plans 1B and 1A. It is again observed that locating large portions of the population in the western part of the Meadowlands causes Plan 1B to rank higher than Plan 1A.

The ranking in terms of average population exposure to HC shows that Plan 1B is best, followed by Plans 1, 1C, and 1A. Since the HC concentration spatial patterns are completely dominated by background air quality, this ranking of the plans is in the order of those having the most population distributed in the western portion of the region where concentrations are lowest. This case represents a situation in which the plans have no effect on regional air quality levels, and hence the receptor impact is completely dominated by the relative location of receptors and land uses within each plan.

It is thus concluded that the degree of impact on critical receptors is especially sensitive to the relative location of the receptors within the plan, and that the relative location of critical receptors and land use categories represents an extremely important consideration in the formulation and evaluation of land use plans.

6.3.3.3 Comparison of Plans for Combined Pollutant Impact

In order to compare the plans on the basis of the combined effects of all pollutants, the multipollutant ranking index for each impact measure was calculated from the formula described in Section 5.3.3 for the Normalized Impact Parameter ranking index. It is to be noted that the ranking of plans on the basis of impact related to the effects on specific receptors is accomplished by this ranking index and is the first known such attempt at ranking plans or air quality relative to effects on specific receptors.

The Normalized Impact Parameter ranking index was calculated by hand from data previously generated in the analysis. The results are listed in Table 18 for each combination of impact measure and receptor category of interest, and are tabulated in order of rank from best to worst. The results show that for average receptor exposures Plan 1 ranks best, followed by Plans 1B, 1A, and 1C for all receptor categories examined. This multipollutant ranking is in close agreement with the subjective ranking based on the visual correlations between air quality patterns and land use plans.

By contrast the multipollutant ranking based on integrated receptor exposure impact measures resulted in every case in the ranking of plans in the order of increasing numbers of receptors. For example, the ranking of plans (from best to worst) for integrated population exposure is in the order of increasing population; namely, Plans 1C, 1, 1A, and 1B. This result is the logical consequence of the defined impact measure which counts both the numbers of receptors as well as the levels of pollutant concentrations to which they are exposed. Consequently, this is a useful measure of the total degree of impact, but the results must be interpreted and used with caution. For example, such an impact measure may be indicative of the total cost of health care associated with regional air quality but would not be indicative of the health risk to the average person.

6.3.4 Land Use/Air Quality Compatibility Score

An example of a new method for evaluating and ranking alternative land use plans is the "land use/air quality compatibility" scoring technique as described in Section 5.2.4. The primary objective of the analysis of plans based on the use of this methodology was to illustrate through direct application to the Meadowlands the versatility of the AQUIP System for carrying out arbitrarily specified air quality impact analyses.

The compatibility score for each plan was calculated by a special routine written with the user-oriented hyperlanguage of the IMPACT program. In general the concentrations for each pollutant were compared with a compatibility criteria for each land use activity on a cell by cell basis within the grid system. The cumulative number of violations of the criteria represents the compatibility score for a plan: the lowest score indicates the greatest compatibility.

The matrix of the land use/air quality compatibility criteria (i.e., the criteria associated with each combination of land use and pollutant) used for this analysis is given in Table 20. These criteria are based entirely on subjective value judgments. Only four land use (or receptor) categories were included: residential area; commercial and industrial area; open space; and students. Both the land use and the air quality data were generated by the LANTRAN program.

The results of the calculation of the compatibility score are given as follows:

PLAN	COMPATIBILITY SCORE
Plan 1	249
Plan 1A	248
Plan 1B	287
Plan 1C	153

The number of violations for each grid cell was displayed by the LANTRAN program for each of the four plans as illustrated in Figures 53 to 56. These figures show the spatial pattern of the degree of conflict between land uses and the air quality concentration levels for all pollutants.

TABLE 20

LAND USE - AIR QUALITY COMPATIBILITY CRITERIA(1)

Land Use Category (or special receptor)	Pollutants				
	TSP	SO_2	CO	HC	NO_X
1. Residential Area	1.0	1.0	1.0	1.0	1.0
2. Commercial & Industrial	2.0	2.0	1.5	2.0	2.0
3. Open Space	1.0	1.0	1.5	0.5	0.5
4. Students	0.25	0.25	0.25	0.25	0.25

(1) Values in matrix represent compatibility criteria, expressed as ratio of allowable pollutant concentration to the annual average ambient air quality standard.

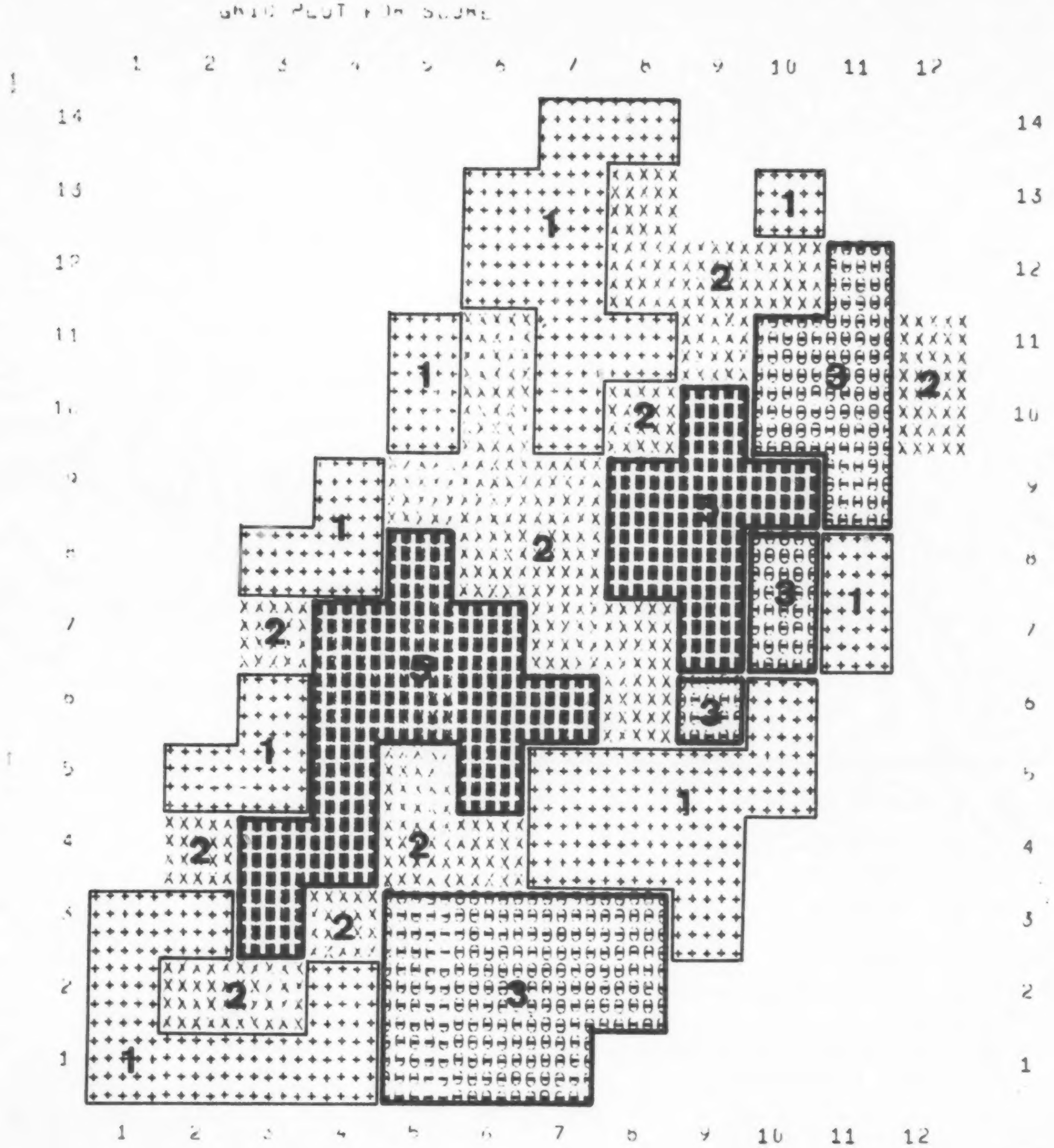
GRID PLOT FOR SCORE
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Figure 53 Land Use - Air Quality Compatibility Score Distribution for Plan 1

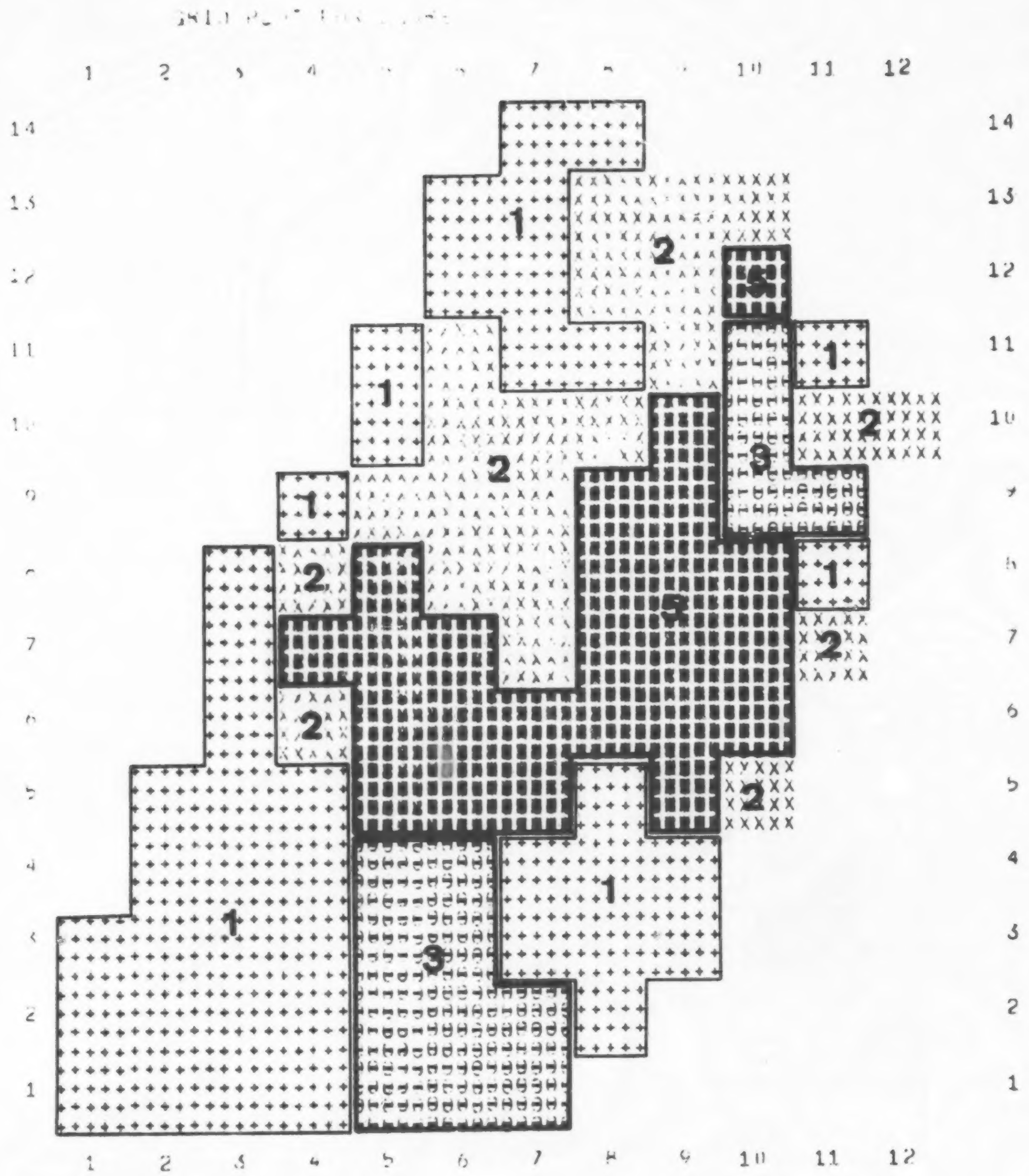
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Figure 54 Land Use - Air Quality Compatibility Score Distribution for Plan 1A

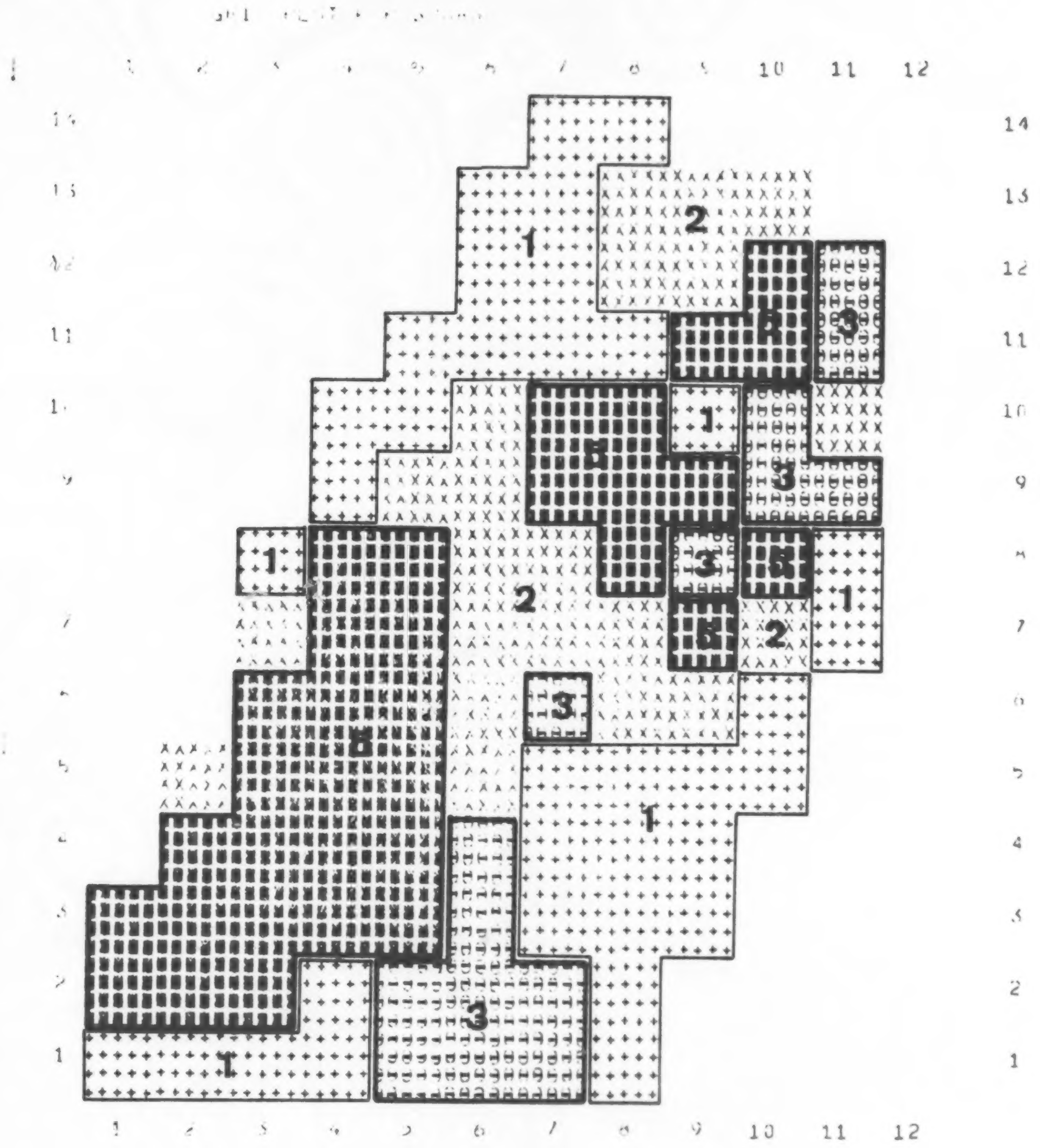
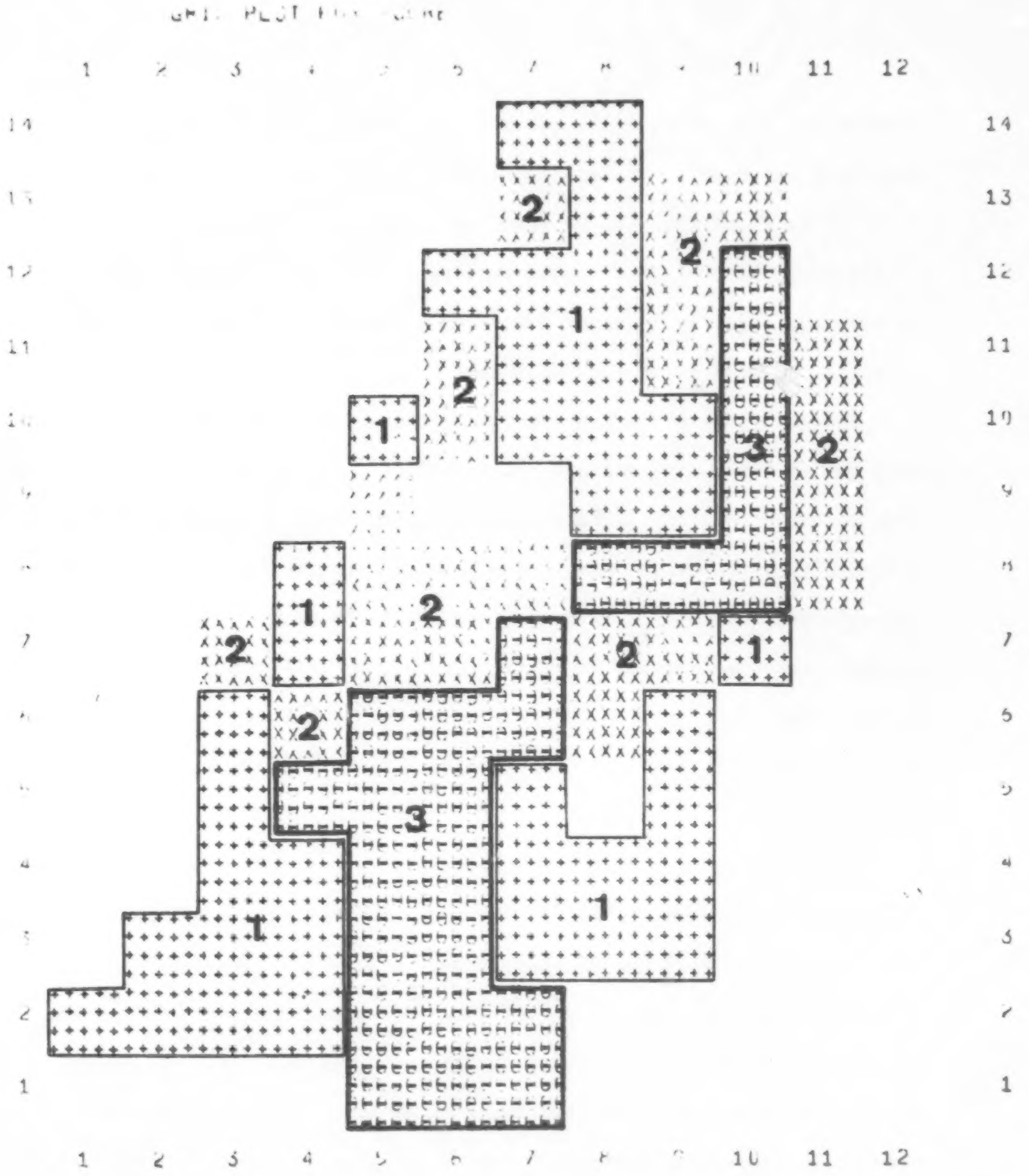


Figure 55 Land Use - Air Quality Compatibility Score Distribution for Plan 1B


GRID PLOT FOR SCORE
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14 13 12 11 10 9 8 7 6 5 4 3 2 1
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• Figure 56 Land Use - Air Quality Compatibility Score Distribution for Plan 1C

Finally Table 21 shows a histogram of the number of grid cells within each plan having a specified number of pollutant violations per grid cell. It is to be noted that the maximum number of violations that can occur within any grid cell is 5 (corresponding to the number of pollutants considered) regardless of the number of different land use compatibility criteria violated by a given pollutant.

The analysis and interpretation of these data shows that every grid cell has at least one land use compatibility criteria which is violated by some pollutant. Plan 1C ranks highest having the least number of land use/air quality conflicts. This is due primarily to the fact that this plan has the least variety of land use categories and in particular has fewer of those land use categories having low tolerance to air quality levels. On the other hand Plan 1B ranks worst having a particularly large number of grid cells with land use compatibility criteria violated by all five pollutants.*

These results are useful to the planner since they show the location and degree of potential conflicts between land use categories and air quality levels. Furthermore they represent a simplified procedure for accounting for the combined effects of several pollutants. However the results do not necessarily represent an appropriate index for ranking plans since they are based on integrated affects, which as discussed previously concerning integrated exposure impact parameters do not always accurately reflect planning goals.

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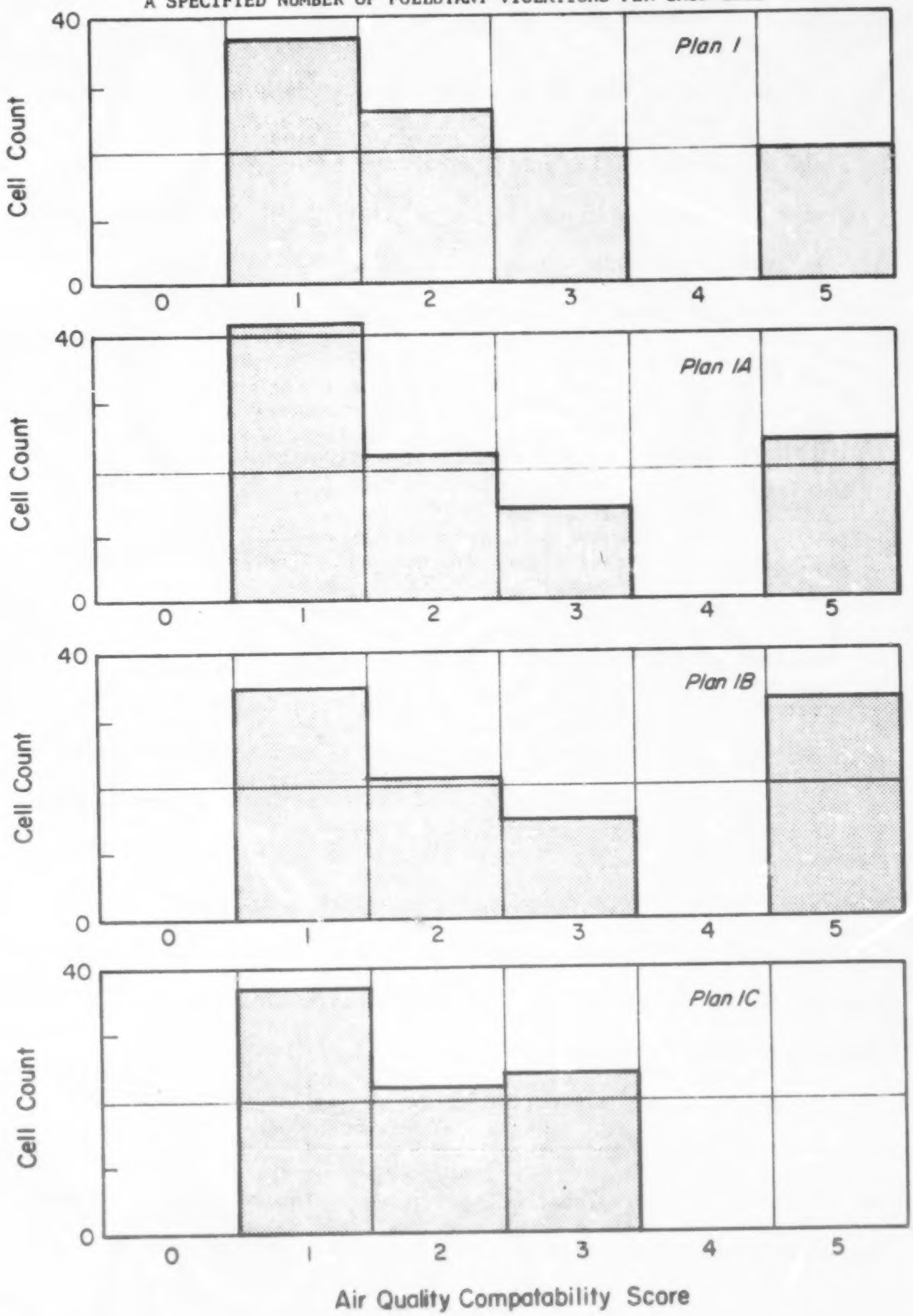
*It is noted that in Plan 1C the land use categories associated with distribution activities were not included in this scoring. As a consequence the high ranking of Plan 1C is somewhat exaggerated although the inclusion of all distribution activities would not change the relative ranking of Plan 1C by this scoring method.

TABLE 21

HISTOGRAM OF THE NUMBER OF GRID CELLS WITHIN EACH GRID CELL HAVING A SPECIFIED NUMBER OF POLLUTANT VIOLATIONS PER GRID CELL



6.3.5 Summary of Plan Evaluations

6.3.5.1 General Criteria and Conditions for the Evaluation

The evaluation of the four alternative Hackensack Meadowlands 1990 Comprehensive Land Use Plans was based primarily on the considerations of:

1. Compliance with ambient air quality standards.
2. The influence of background concentrations on total air quality within each plan.
3. Average regional air quality concentration levels.
4. The percent variation in total air quality among the plans on a pollutant by pollutant basis.
5. Average exposures of critical receptors and land use categories to pollutant concentrations.

A subjective evaluation of plans was carried out by means of a visual examination of air quality contours and the correlation of such contours with the land use categories of each plan. A quantitative analysis and evaluation of plans was carried out by the calculation of quantitative measures of impact. This quantitative evaluation was based primarily on "averaged" impacts (such as average regional concentration levels or average levels of exposure to specific receptors) rather than "integrated" impacts (which are proportional to both average concentration levels and the total number of receptors affected).

In addition to these criteria, the evaluation of the plans was subject to other constraints and general considerations. In particular the analysis was oriented toward regional effects based on the calculation of mean annual pollutant concentration levels. The analysis considered the effects on regional air quality (and on critical receptors) resulting primarily from differences among the four plans in 1) the percent mix of land use categories; 2) the relative locations of land uses; and 3) the relative intensity of land use activities. The relationship between pollutant concentrations and effects such as health effects and economic consequences were not considered. Moreover, the analysis did not consider locallized or microscale impacts. Finally, the analysis did not consider the interrelationship between air pollution effects and other environmental concerns such as water quality and solid waste disposal.

6.3.5.2 Results of Plan Evaluations

It was found that all four land use plans behaved similarly relative to compliance with ambient air quality standards. Three of the pollutants, SO_2, CO, and NO_x, were found to comply with standards in all plans. Two of the pollutants, TSP and HC, were found to exceed ambient air quality standards in all four plans.

The visual examination of air quality contours showed relatively small but distinctly observable variations among the plans for each given pollutant with the exception of HC. In all cases it was found that background concentration levels represent 65% to 99% of total air quality within the region (depending on the specific plan and pollutant) and thus represent the most significant influence on concentration levels and spatial patterns for each of the plans and each of the pollutants.

It was concluded that particulates represent a critical air quality problem in all plans since background concentrations as well as total air quality exceed standards in the 1990 time period. On the other hand, SO_2

is not considered to be a critical problem in terms of regional air quality since predicted concentration levels are well within the limits of the ambient air quality standard. Furthermore the observed variation in impacts on average regional air quality among Plans 1, 1A, and 1B is less than 6% while the impact of Plan 1C on regional air quality is 15% greater than for Plan 1. This indicates that Plans 1, 1A, and 1B are highly preferable to Plan 1C in terms of average SO_2 air quality.

Air quality concentrations for CO are not considered to be a critical problem on the regional scale for Plans 1, 1A, and 1C, since concentrations are well within the ambient air quality standards. In Plan 1B, however, air quality reaches approximately 90% of the standard and thus becomes an issue of critical concern, especially since under such circumstances locallized concentrations resulting from short period peak taffic conditions have a high probability of exceeding standards.

Air quality for HC is a critical consideration in all plans because of the large factor by which standards are exceeded. Just how critical it is, however, depends strongly on the goals and judgment of the planner, especially since the primary concern for HC is with effects on plant life and the formation of photochemical oxidants rather than with direct health effects. Furthermore, since background levels represent on the order of 99% of total air quality in all plans, it is clear that land use planning is an ineffective approach to abating HC air quality problems. However, by appropriately locating critical receptors within a land use plan, the planner can achieve minimum exposures of critical receptors and land use categories.

Air quality for NO_x is not considered to be a critical consideration since total air quality levels are well below standards. In addition variations in average regional concentration levels among the plans are relatively small (approximately 7%).

These results show that in many cases the planner can be neutral in his choice of a plan based on air quality considerations. In particular these results indicate that in the presence of high background levels, total air quality levels are extremely insensitive to the choice of a plan, even when emissions resulting from alternatives differ significantly. Thus when total pollutant concentrations are well below standards, the consideration of air quality is not necessarily a critical factor in choosing among alternative land use plans. For example, it is noted that in plans where total air quality for SO_2, CO, and NO_x is well within ambient air quality standards, the planner can be relatively neutral in his choice of a plan, provided that he is only concerned with these specific pollutants.

As a result of the evaluation of plans on the basis of single pollutant impacts, the ranking for TSP, SO_2, and NO_x was found to be (from best to worst) Plan 1, 1B, 1A, and 1C for nearly all choices of impact measure based on average exposures (in contrast to integrated exposure impacts). The ordering of plans for both CO and HC was found to depend strongly on the specific receptors impacted. However, on the basis of average CO exposures, Plan 1 was judged best generally for all receptors of interest. For HC, Plan 1 was judged best on the basis of impact on regional air quality considerations while Plan 1B was judged best on the basis of average population exposures (a result strongly influenced by the location of most residential areas in the western part of the Meadowlands).

The correlation between land uses and regional air quality showed generally that lowest average regional pollutant concentration levels for TSP, SO_2, and NO_x are achieved by those plans having the least percentage of land use devoted to manufacturing, and lowest levels for CO result from plans having the least vehicle trip miles. Similarly, it was found that the location of manufacturing land use within a plan is the dominant influence on TSP, SO_2, and NO_x air quality contours, and that the location of roadways within a plan is the dominant influence on CO air quality contours.

In addition, it was generally found that those plans having the least pollutant impact on population and residential areas were those having the most population and residential areas located in the western portions of the region (or more specifically, in those regions of the plan where background concentration levels are lowest). Plans 1 and 1B generally ranked highest in terms of impact on population--Plan 1 because of its lower regional average concentrations and Plan 1B because of its better location of residential areas within the plan.

Finally, it was observed that all land use categories other than manufacturing and transportation, have a significantly smaller impact on regional air quality. Thus in the presence of high background levels, such land uses can in general be located arbitrarily within the land use plan without any significant impact on regional concentration levels or air quality contours. However, the relative location of such land uses within a plan can cause a significant change in the degree of impact on critical receptors and land use activities. Consequently it is concluded that the consideration of air pollution in the planning process is important not only as a means to long term air quality improvement but also as a means of reducing impacts on sensitive receptors.

6.4 Ranking of the Alternative Land Use Plans

As a final step in the evaluation and ranking of the land use plans, the Normalized Impact Parameter ranking index was calculated for a variety of choices of impact parameters and receptors of interest. It was judged, however, that for the purposes of ranking the land use plans, impact parameters based on average receptor exposures are the most meaningful representation of concerns and objectives in the planning process. The use of impact parameters based on integrated receptor exposures does provide useful information, but the results of the ranking based on such integrated impacts are not as meaningful to planners who must also respond to other planning considerations and constraints. The logical result of evaluating plans on the basis of integrated impact measures would be the selection of a plan consisting predominantly of those land use categories most tolerant to air quality, a result which may be in direct conflict to the needs of the planner to provide housing and employment, to fulfill transportation demands, and to achieve balanced land uses.

Examination of Table 18 shows that the resultant ranking of plans based on the Normalized Impact Parameter ranking index for average receptor exposures is (from best to worst) Plan 1, 1B, 1A, and 1C. This ranking occurs for nearly all receptors of interest and is consistent with intuitive judgment based upon the visual examination of air quality contours. Moreover this multipollutant ranking order is the same as the ranking of plans based on single pollutants for most receptors of interest.

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GLOSSARY

Activity, Activity Level - basic land use and transportation planning units of intensity of use - vehicles per day on a highway, acres of residential land use, square feet of industrial plant space.

Activity Index - a numerical conversion factor to transform the level of activity specified for a land use category into demand for fuel for heating purposes.

Air Quality Contour - a contour line in a plane (usually the horizontal or vertical) representing points of equal concentrations for a specified air pollutant.

Air Quality Criteria - factors used in this study that represent a basis for decision-making, for example ambient air quality standards.

Air Quality Prediction - the calculation of current or future air pollutant concentrations at specified receptor points resulting from the action of meteorological conditions on source emissions.

Albedo - the fraction of solar radiation reflected from the ground surface.

Ambient Air - that portion of the atmosphere, external to buildings, to which the general public has access.

Ambient Air Quality - concentration levels in ambient air for a specified pollutant and a specified averaging time period within a given geographic region.

Ambient Air Quality Standard - a level of air quality established by federal or state agencies which is to be achieved and maintained; primary standards are those judged necessary, with an adequate margin of safety, to protect the public health; secondary standards are those judged necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

AQUIP - an acronym for Air Quality for Urban and Industrial Planning, a computer-based tool for incorporating air pollution considerations into the land use and transportation planning process.

Atmospheric Boundary Layer - the lower region of the atmosphere (to altitudes of 1 to 2 km) where meteorological conditions are strongly influenced by the ground surface features.

Atmospheric Dispersion Model - a mathematical procedure for calculating air pollution concentrations that result from a specified array of emission sources and a specified set of meteorological conditions.

Average Receptor Exposure - a measure of the average impact of air quality levels on specific receptors; the measure is based on the integrated receptor exposure divided by the total number of receptors in the study region.

Background Air Quality - levels of pollutant concentrations within a study region which are the result of emissions from all other sources not incorporated in the model for the study region.

Background Emissions - the emissions inventory applicable to the background region; that is, all emission sources not explicitly included in the inventory for the study region.

Climatology - the study of long term weather as represented by statistical records of parameters such as winds, temperature, cloud cover, rainfall, and humidity which determine the characteristic climate of a region; climatology is distinguished from meteorology in that it is primarily concerned with average, not actual, weather conditions.

Concentrations - a measure of the average density of pollutants usually specified in terms of pollutant weight per unit (typically in units of micrograms per cubic meter), or in terms of relative volume of pollutant per unit volume of air (typically in units of parts per million).

Default Parameters - values associated with a parameter for a category of activities (such as heavy manufacturing) assigned to the activity parameter for a subcategory of activities (such as electrical machinery production) when the actual value for the subcategory is not known.

Degree Days (Heating Degree Days) - the sum of negative departures of average temperature from 65°F; used to determine demand for fuel for heating purposes.

Effective Stack Height - the height of the plume center-line when it becomes horizontal.

Emission Factor - a numerical conversion factor applied to fuel use and process rates to determine emissions and emission rates.

Emissions - effluents into the atmosphere, usually specified in terms of weight per unit time for a given pollutant from a given source.

Emissions Inventory - a data set describing the location and source strength of air pollution emissions within a geographical region.

Emissions Projection - the quantitative estimate of emissions for a specified source and a specified future time.

Equivalent Ambient Air Quality Standards - air quality levels adopted in this study to permit analysis of all air pollutants in terms of annual averages; in cases where state and federal annual standards do not exist, the adopted levels are based on the extrapolation of short period standards.

Fuel Related Sources, Fuel Emissions - fuel related sources use fuel to heat area, or to raise a product to a certain temperature during an industrial process, or for cooking in the house; they produce fuel emissions. (See also Non-Fuel Related Sources.)

Fuel Use Propensity, Fuel Demand - the total heat requirement (space heating plus process heating) determines the fuel demand; the propensity to use a particular fuel or fuels determines the actual amounts of various fuels used to satisfy the heat requirement.

Heating Requirements - the demand for fuel is specified in terms of the heating requirements:

space heating - the fuel used to heat area, such as the floor space of a school in the winter, is that required for space heating; the heat content or value of that fuel defines the space heating requirement (BTUs, British Thermal Units of heating content).

non-space heating, process heating - the fuel used to raise a product to a certain temperature during an industrial process or for cooking (with gas) in the home is that required for process heating or non-space heating. It is generally not related to outside temperature whereas space heating requirements are.

percent space heating, percent process heating - the relative proportion of a fuel or its heat content that is used for space heating or process heating defines,respectively, the percent space heating or percent process heating.

Impact Measure (or Parameter) - a quantitative representation of the degree of impact on air quality or specific receptors resulting from concentrations of specified pollutants.

Influence Region - the influence region for a study area is the geographical region containing the emission sources responsible for at least 90% of the ground level concentrations (averaged throughout the study area) of all pollutants considered.

Integrated Receptor Exposure - a measure of the total impact of air quality levels on specific receptors; the measure is based on the summation within the study region of the number of receptors times the concentration levels to which they are exposed.

Inventories - the aggregation of all fuel and process emissions sources is called the emissions inventory; the components for use with the model:

current inventory - all sources for 1969

background inventory - all sources for 1990 not directly related to the meadowlands plans.

plan inventories - all sources for 1990 related to the Meadowlands plans; this excludes any source outside the Meadowlands boundary and also excludes existing major single sources and the highway network.

Isopleth - the locus of points of equal value in a multidimensional space.

Land Use Intensity - the level of activity associated with a given land use category, for example the population density of residential areas.

Land Use Mix - the percent of total study region area allocated to specific land use categories.

Meteorology - the study of atmospheric motions and phenomena.

Microscale Air Quality - the representation of air quality in a geographical scale characterized by distances between source and receptor ranging from a few meters to a few tens of meters.

Mixing Depth - the vertical distance from the ground to the base of a stable atmospheric layer (also called inversion height).

Model Calibration - the process of correlating model predictions with observed (measurements) data, usually to determine calibration factors relating predicted to observed values for each pollutant.

Model Validation - the detailed investigation of model results by comparison with measured values to identify systematic discrepencies that may be corrected by alterations of model parameters or model mechanics.

Non-Fuel Related Sources, Process Emissions, Separate Process Emissions - non-fuel related sources do not burn fuel primarily for heating purposes or do not burn fuel at all; these include transportation sources, incineration, and certain industrial processes; they produce process or separate process emissions. (See also Fuel Related Sources.)

Ranking Index - a quantitative representation of the net impact on air quality or specific receptors resulting from all pollutants being considered.

Receptor - a physical object which is exposed to air pollution concentrations; objects may be animate or inanimate, and may be arbitrarily defined in terms of size, numbers, and degree of specificity of the object.

Receptor Point - a geographical point at which air pollution concentrations are measured or predicted.

Regional Air Quality - the representation of air quality in a geographical scale characterized by large areas, for example, on the order of 50 square kilometers or greater.

Schedule - number of hours per year a fuel burning activity will consume fuel; used to determine heating requirements.

Source - any stationary or mobile activity which produces air pollutant emissions.

Source Geometry - all sources for modeling purposes are considered to exist as a point, line, or area, defined as follows:

point source - a single major emitter located at a point.

line source - a major highway link, denoted by its end points.

area source - a rectangular area referenced to a grid system; includes not only area-wide sources, such as residential emitters, but single emitters and highway links deemed too small to be considered individual point or line sources by the model.

Stability Category - a classification of atmospheric stability conditions based on surface wind speed, cloud cover and ceiling, supplemented by solar elevation data (latitude, time of day, and time of year).

Stability Wind Rose - a tabulation of the joint frequency of occurrences of wind speed and wind direction by atmospheric stability class at a specific location.

Total Air Quality - the air quality at a receptor point resulting from background emission sources and from emission sources specifically within the study region.

Trapping Distance - the distance downwind of a source at which vertical mixing of a plume begins to be significantly inhibited by the base of the stability layer, and gaussian vertical distribution can no longer be assumed.

Wind Sector - a 22-1/2 degree wind direction range whose center-line is one of the sixteen points of the compass.

Planning Agencies Surveyed

1. California Air Resources Board
   1108 Fourteenth Street
   Sacramento, California 95814

2. California Department of Public Works
   Division of Highways, Materials and Research Dept.
   5900 Fulsom Blvd.
   Sacramento, California 95819

3. Metropolitan Washington Council of Governments
   1225 Connecticut Avenue Northwest
   Washington, D.C. 20036

4. Office of Planning and Programming
   Washington, D.C. Dept. of Highways and Traffic
   415 Twelfth Street N.W.
   Washington, D.C. 20004

5. Argonne National Laboratories
   Center for Environmental Studies
   9700 So. Cass Avenue
   Argonne, Illinois 60439

6. Boston Redevelopment Agency
   New City Hall
   Boston, Mass. 02109

7. Boston Transportation Planning Review
   100 Boylston Street
   Boston, Massachusetts 02116

8. Metropolitan Area Planning Council
   44 School Street
   Boston, Massachusetts 02108

9. East-West Gateway Coordinating Council
   St. Louis Area Council of Governments
   720 Olive Street
   St. Louis, Mo. 63101

10. Air Pollution Control Division
    St. Louis County Health Department
    801 South Brentwood Boulevard
    Clayton, Mo. 63105

11. St. Louis County Dept. of Planning
    Government Center, 7900 Forsyth Street
    Clayton, Mo.

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12. Hackensack Meadowlands Development Commission
1099 Wall Street West
Lyndhurst, New Jersey 07071

13. Middlesex County Planning Board
County Administration Bldg., JFK Square
New Brunswick, New Jersey 08901

14. New Jersey Dept. of Transportation
1035 Parkway Avenue
Trenton, New Jersey 08625

15. Nassau-Suffolk Regional Planning Board
Veterans Memorial Highway
Hauppage, L.I., New York 11787

16. Interstate Sanitation Commission
10 Columbus Circle
New York, New York 10019

17. New York City Department of Air Resources
New York City Environmental Protection Administration
57 Astor Place
New York, New York 10003

18. Department of City Planning
New York City Planning Commission
2 Lafayette Street
New York, New York

19. New York City Office
New York State Office of Planning Services
1841 Broadway
New York, New York

20. New York State Urban Development Corporation
1345 Avenue of the Americas
New York, New York 10019

21. Regional Plan Association
230 West 41st Street
New York, New York

22. Tri-State Transportation Commission
100 Church Street
New York, New York 10007

23. Division of Air Pollution Control
Pennsylvania Department of Health
Harrisburg, Pennsylvania 17120

24. Pennsylvania Department of Transportation
Transportation and Safety Building
Harrisburg, Pennsylvania 17120

ATTACHMENT B
AMBIENT AIR QUALITY CONCENTRATIONS FOR THE 1990 HACKENSACK MEADOWLANDS PLANS

TABLE B-1

LISTING OF AMBIENT AIR QUALITY MAPS

Figure	Air Quality	Averaging Period	Pollutant	Plan
B-1	Background	Annual	TSP	-
B-2	"	"	SO_2	-
B-3	"	"	CO	-
B-4	"	"	HC	-
B-5	"	"	NO_x	-
B-6	Total	Annual	TSP	1
B-7	"	"	"	1A
B-8	"	"	"	1B
B-9	"	"	"	1C
B-10	Total	Annual	SO_2	1
B-11	"	"	"	1A
B-12	"	"	"	1B
B-13	"	"	"	1C
B-14	Total	Annual	CO	1
B-15	"	"	"	1A
B-16	"	"	"	1B
B-17	"	"	"	1C
B-18	Total	Annual	HC	1
B-19	"	"	"	1A
B-20	"	"	"	1B
B-21	"	"	"	1C
B-22	Total	Annual	NO_x	1
B-23	"	"	"	1A
B-24	"	"	"	1B
B-25	"	"	"	1C
B-26	Total	Summer	TSP	1
B-27	"	"	"	1A
B-28	"	"	"	1B
B-29	"	"	"	1C

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TABLE B-1 (cont)

B-30	Total	Summer	SO_2	1
B-31	"	"	"	1A
B-32	"	"	"	1B
B-33	"	"	"	1C
B-34	Total	Summer	CO	1
B-35	"	"	"	1A
B-36	"	"	"	1B
B-37	"	"	"	1C
B-38	Total	Summer	HC	1
B-39	"	"	"	1A
B-40	"	"	"	1B
B-41	"	"	"	1C
B-42	Total	Summer	NO_x	1
B-43	"	"	"	1A
B-44	"	"	"	1B
B-45	"	"	"	1C
B-46	Total	Winter	TSP	1
B-47	"	"	"	1A
B-48	"	"	"	1B
B-49	"	"	"	1C
B-50	Total	Winter	SO_2	1
B-51	"	"	"	1A
B-52	"	"	"	1B
B-53	"	"	"	1C
B-54	Total	Winter	CO	1
B-55	"	"	"	1A
B-56	"	"	"	1B
B-57	"	"	"	1C
B-58	Total	Winter	HC	1
B-59	"	"	"	1A
B-60	"	"	"	1B
B-61	"	"	"	1C
B-62	Total	Winter	NO_x	1
B-63	"	"	"	1A
B-64	"	"	"	1B
B-65	"	"	"	1C

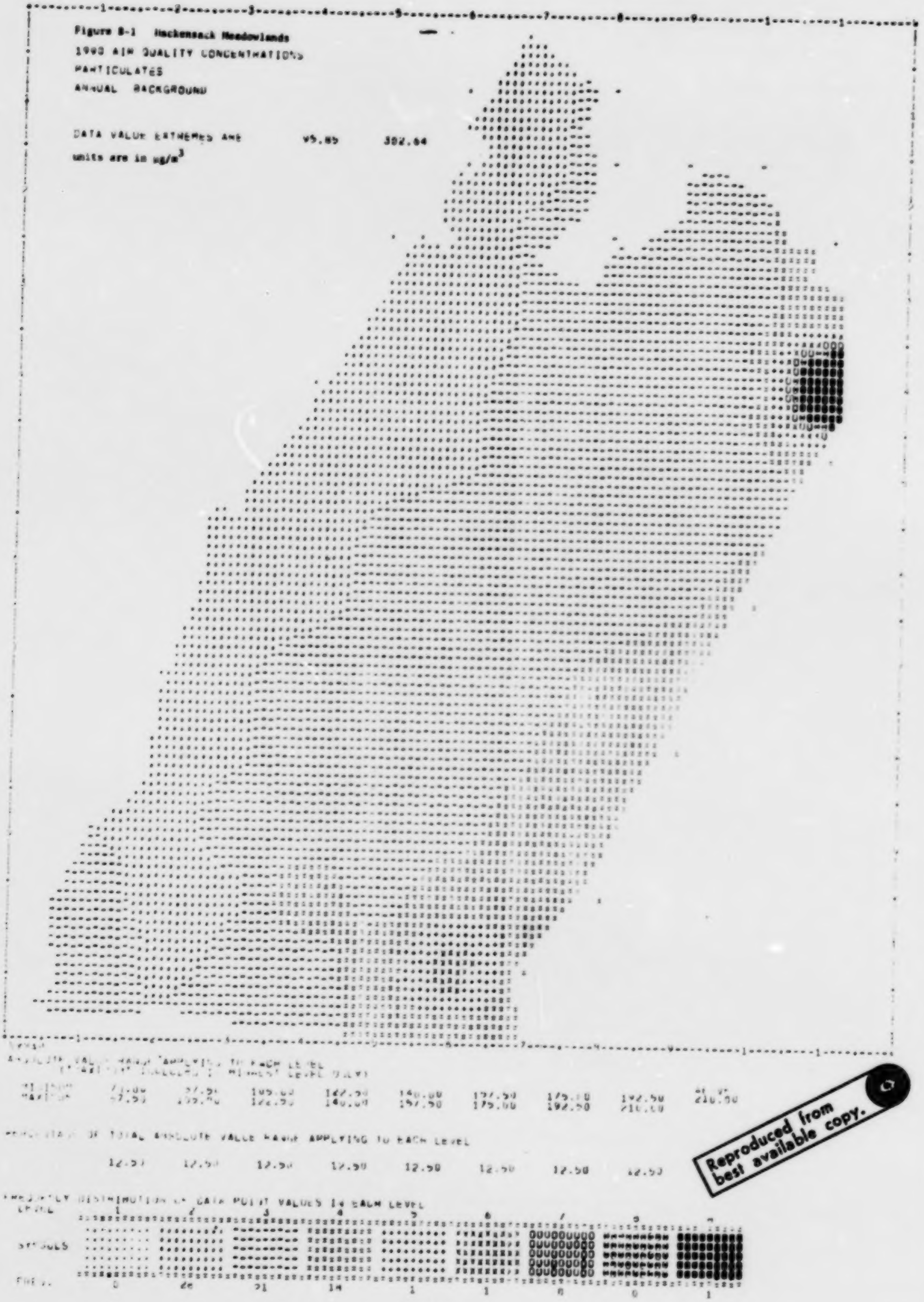


Figure 8-1 Hackensack Meadowlands

```
1990 AIR QUALITY CONCENTRATIONS
PARTICULATES
ANNUAL BACKGROUND

DATA VALUE EXTREMES ARE        95.85      392.64
units are in ug/m3
```

```
LEGEND
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM      70.00     87.50    105.00    122.50    140.00    157.50    175.00    192.50    [illegible]
MAXIMUM      87.50    105.00    122.50    140.00    157.50    175.00    192.50    210.00    210.50

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             12.50     12.50     12.50     12.50     12.50     12.50     12.50     12.50

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
LEVEL          1         2         3         4         5         6         7         8         9

SYMBOLS

FREQ.          0        26        21        14         1         1         0         0         1
```

Reproduced from best available copy.

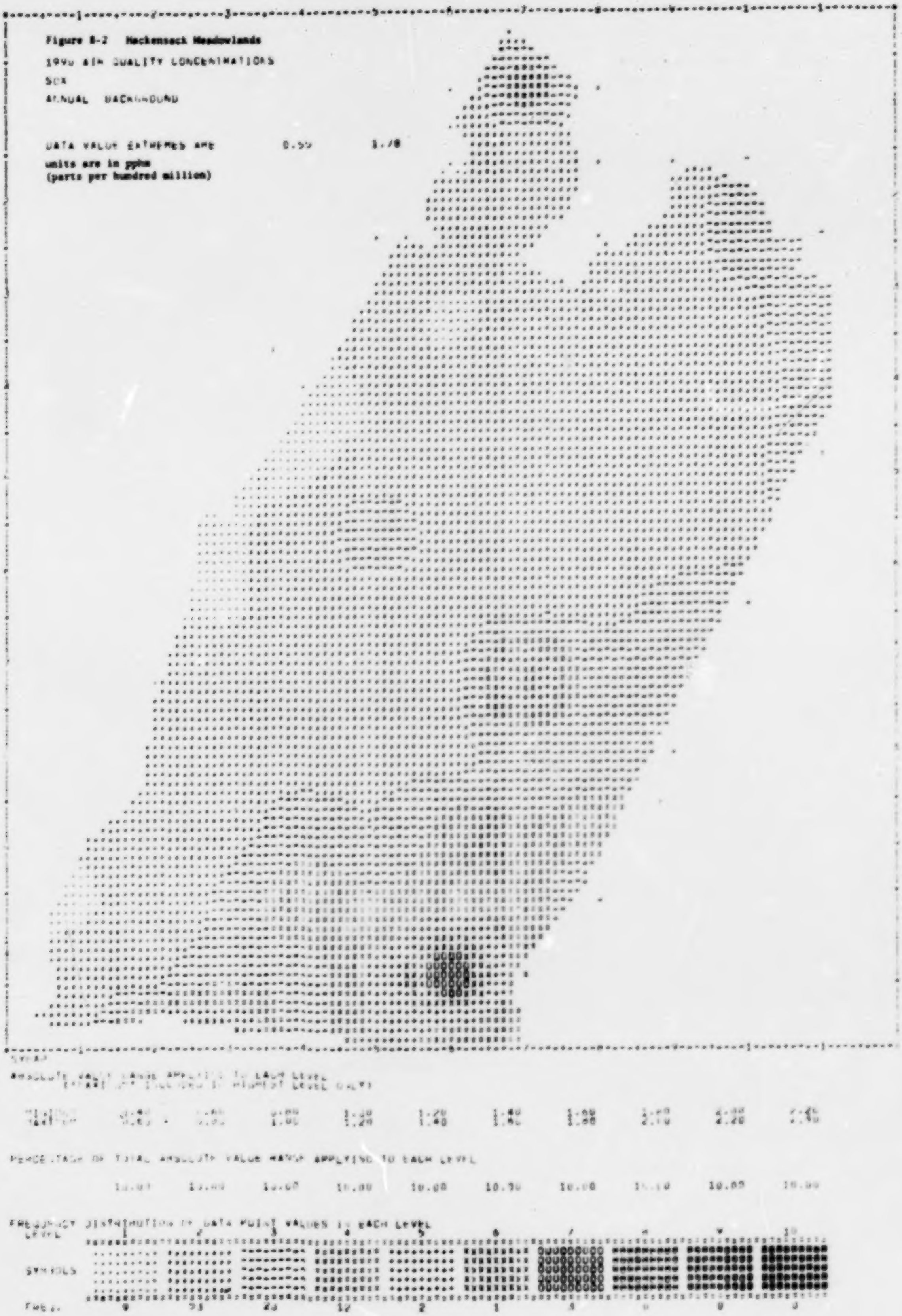


Figure 8-2 Hackensack Meadowlands

```
1990 AIR QUALITY CONCENTRATIONS
SOX
ANNUAL  BACKGROUND

DATA VALUE EXTREMES ARE          0.55        1.78
```

units are in pphm
(parts per hundred million)

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM      0.40     0.60     0.80     1.00     1.20     1.40     1.60     1.80     2.00     2.20
MAXIMUM      0.60     0.80     1.00     1.20     1.40     1.60     1.80     2.00     2.20     2.40

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
LEVEL          1        2        3        4        5        6        7        8        9       10

SYMBOLS

FREQ.          0       21       23       12        2        1        3        0        0        0
```

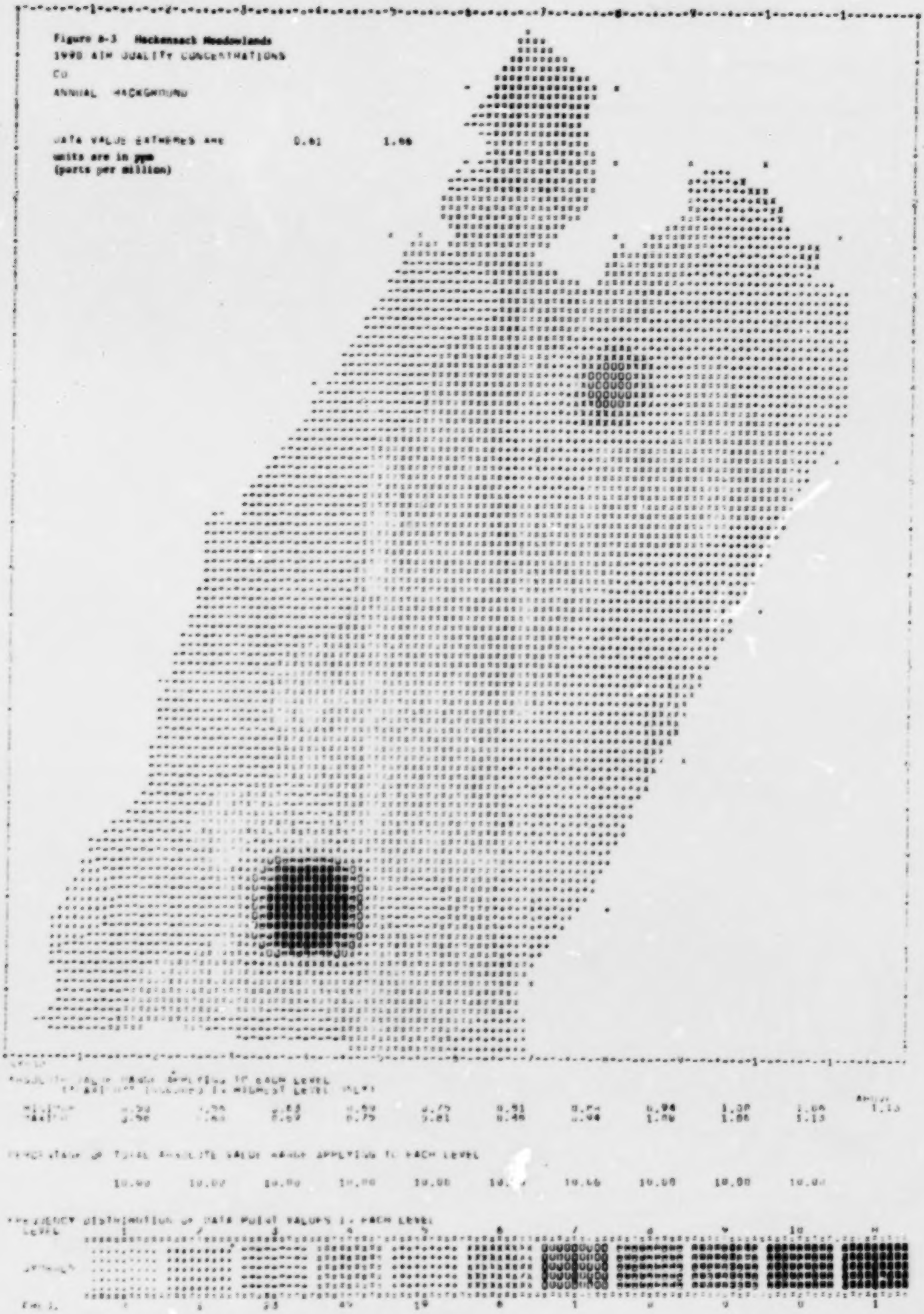


Figure 6-3 Hackensack Meadowlands

1990 AIR QUALITY CONCENTRATIONS

CO

ANNUAL BACKGROUND

DATA VALUE EXTREMES ARE 0.61 1.06

units are in ppm
(parts per million)

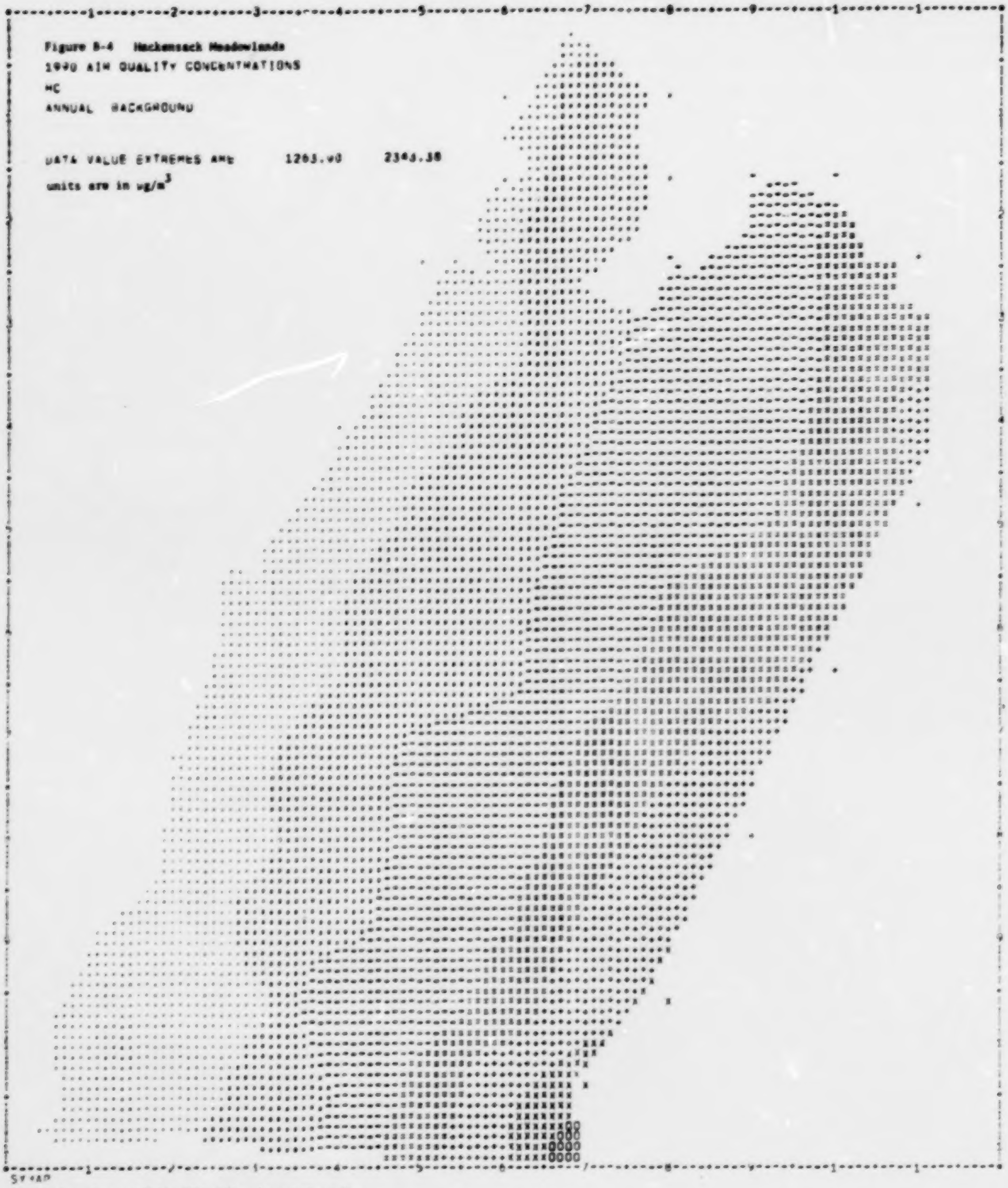


Figure 8-4 Hackensack Meadowlands
1990 AIR QUALITY CONCENTRATIONS
HC
ANNUAL BACKGROUND

DATA VALUE EXTREMES ARE 1263.00 2343.38
units are in ug/m^3

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM   1248.00 . 1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00
 MAXIMUM   1404.00 . 1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00   2808.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

           10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL       1         2         3         4         5         6         7         8         9         10

 SYMBOLS

 FREQ.       29        41        43        16        11        3         0         1         0         0
```

Figure B-5 Hackensack Meadowlands

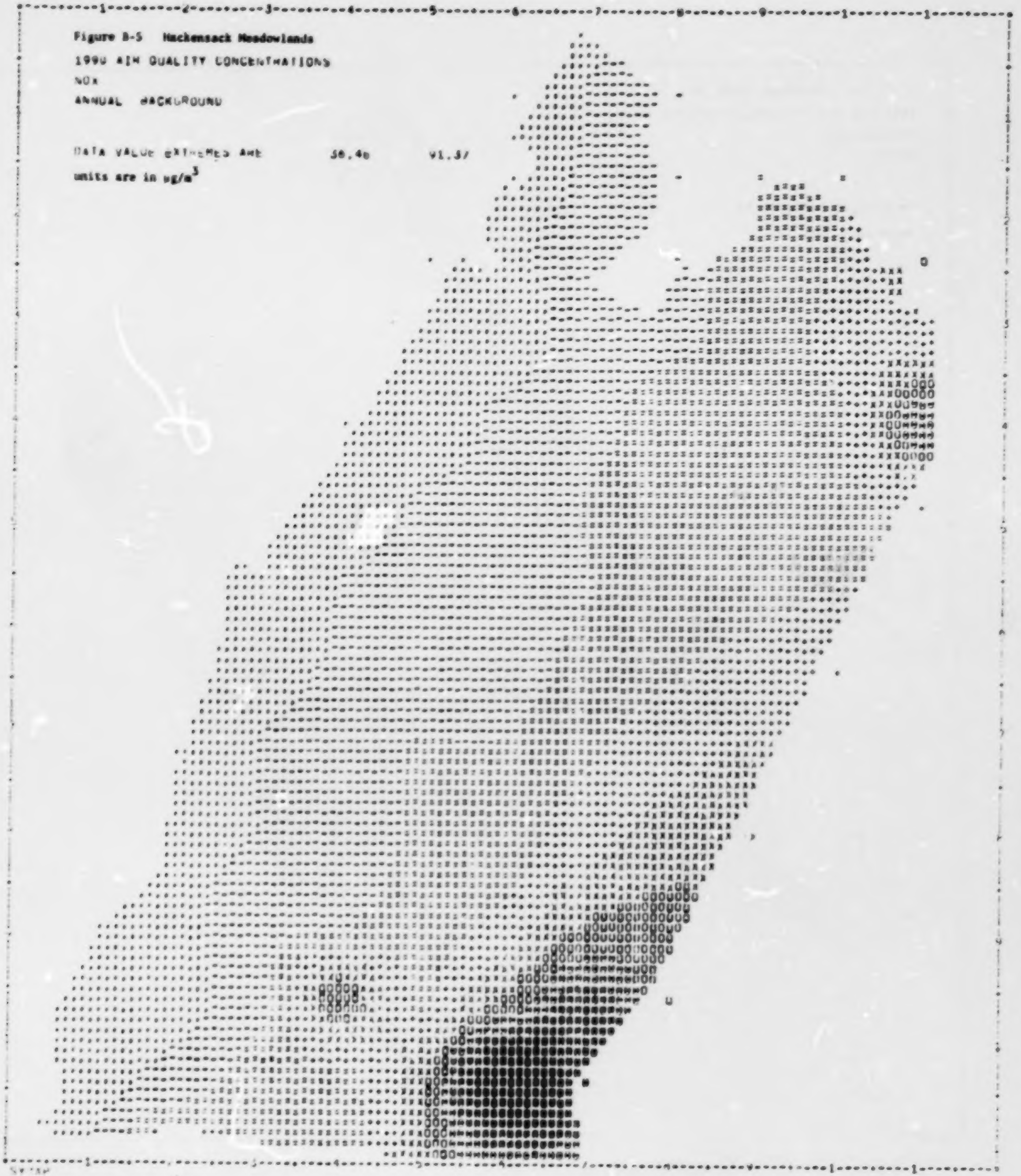
1990 AIR QUALITY CONCENTRATIONS

NOx

ANNUAL BACKGROUND

DATA VALUE EXTREMES ARE 30.46 91.37

units are in µg/m³



```
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM   30.00   35.00   40.00   45.00   50.00   55.00   60.00   65.00   70.00   75.00    ABOVE
MAXIMUM   35.00   40.00   45.00   50.00   55.00   60.00   65.00   70.00   75.00   80.00    80.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

          10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL      1       2       3       4       5       6       7       8       9      10       H

SYMBOLS

FREQ.       4      14      27      27       9       7       6       2       1       1       1
```

Figure B-6 Hackensack Meadowlands Plan 1

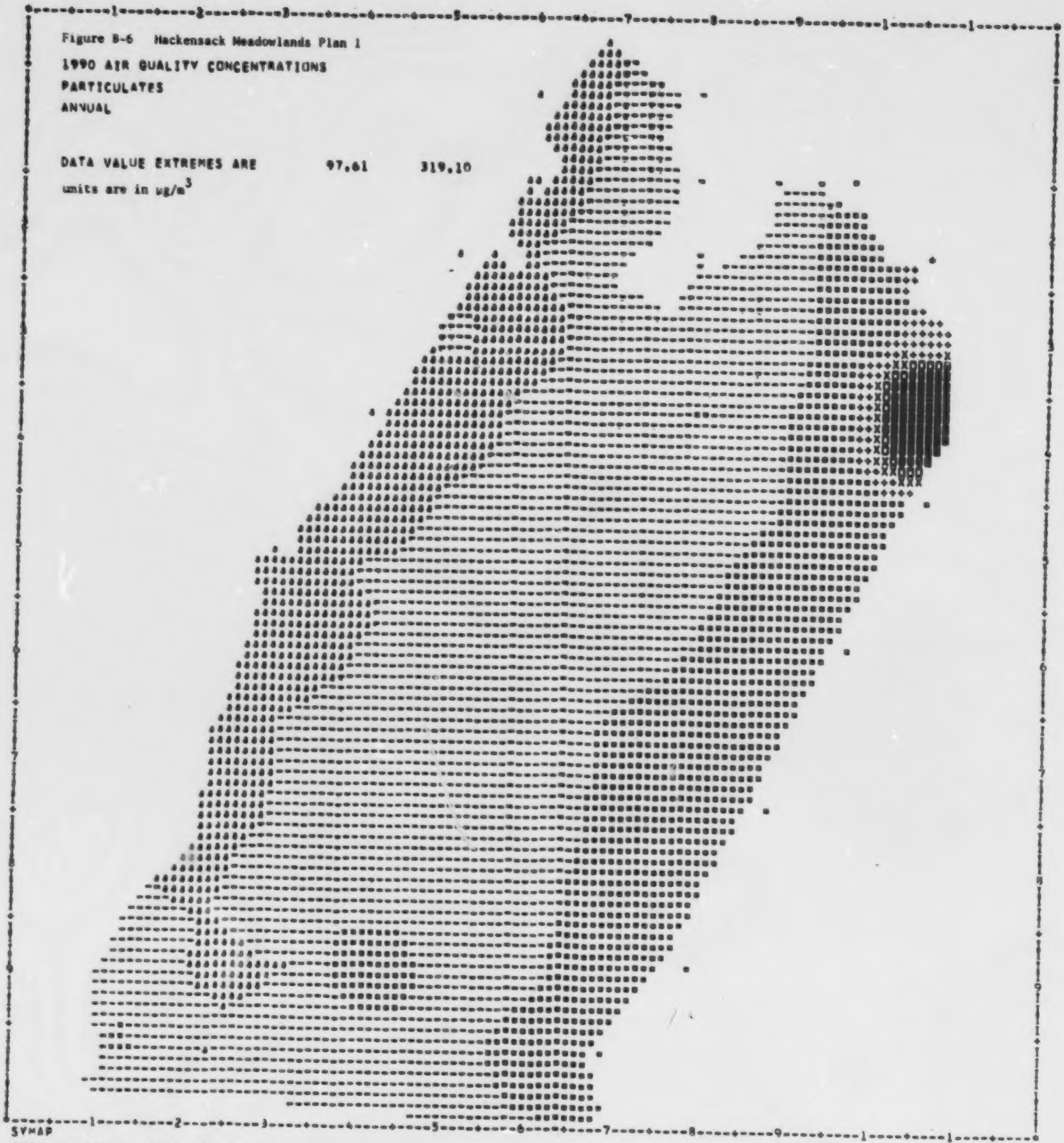
1990 AIR QUALITY CONCENTRATIONS

PARTICULATES

ANNUAL

DATA VALUE EXTREMES ARE 97.61 319.10

units are in $\mu g/m^3$



```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM     70.00     87.50    105.00    122.50    140.00    157.50    175.00    192.50    ABOVE
 MAXIMUM     87.50    105.00    122.50    140.00    157.50    175.00    192.50    210.00    210.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             12.50     12.50     12.50     12.50     12.50     12.50     12.50     12.50

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL         1         2         3         4         5         6         7         8         H
          ****************************************************************************************
          ......... ######### --------- ********* +++++++++ XXXXXXXXX OOOOOOOOO ØØØØØØØØØ █████████
 SYMBOLS  ......... ######### --------- ********* +++++++++ XXXXXXXXX OOOOOOOOO ØØØØØØØØØ █████████
          ......... ######### --------- ********* +++++++++ XXXXXXXXX OOOOOOOOO ØØØØØØØØØ █████████
          ****************************************************************************************
 FREQ.         0        18        53        26         2         0         0         0         1
```

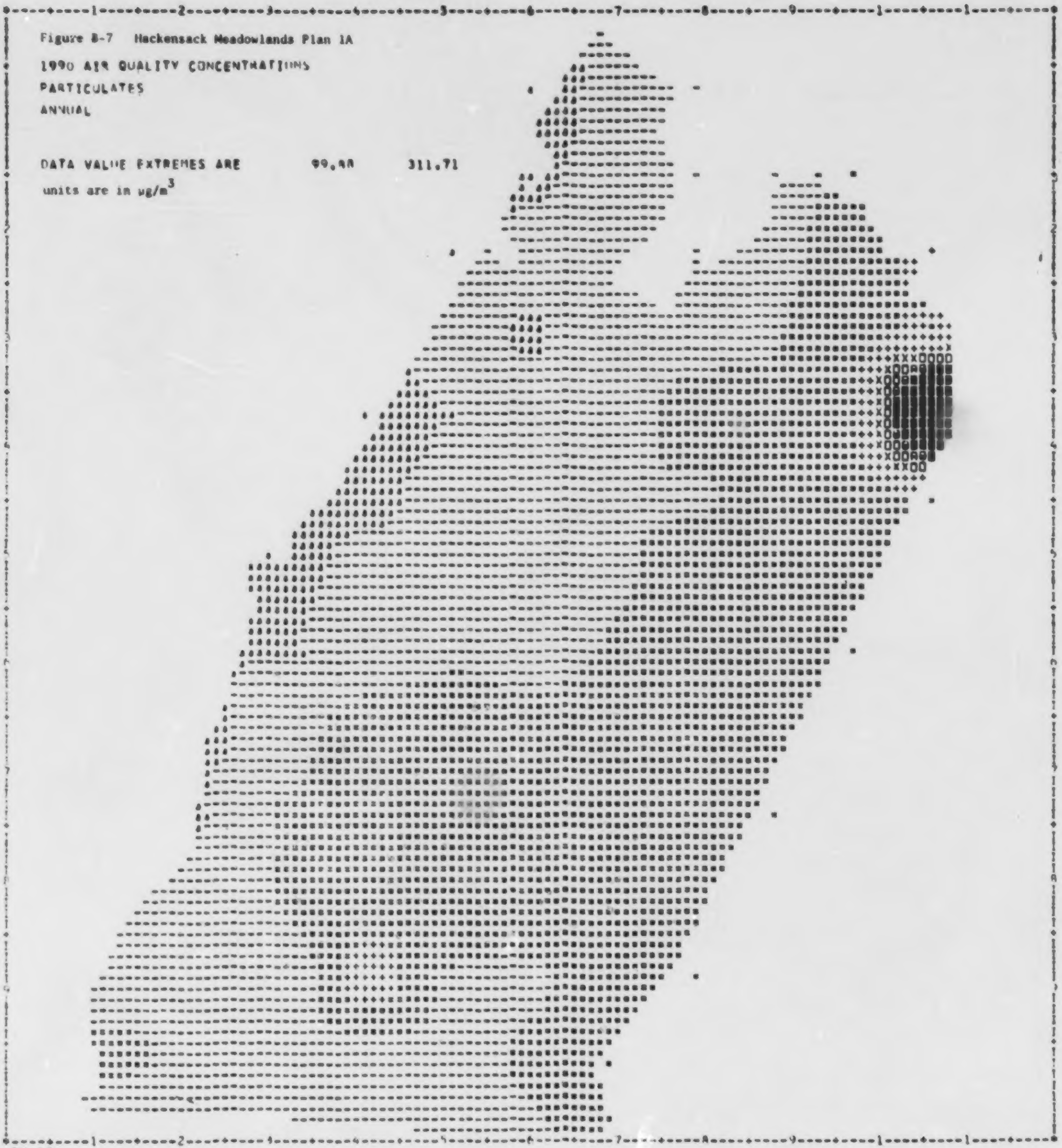


Figure 8-7 Hackensack Meadowlands Plan 1A

1990 AIR QUALITY CONCENTRATIONS
PARTICULATES
ANNUAL

DATA VALUE EXTREMES ARE 99.88 311.71
units are in µg/m³

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)
                                                                                            ABOVE
 MINIMUM     70.00     87.50    105.00    122.50    140.00    157.50    175.00    192.50    210.00
 MAXIMUM     87.50    105.00    122.50    140.00    157.50    175.00    192.50    210.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             12.50     12.50     12.50     12.50     12.50     12.5      12.50     12.50

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL        1         2         3         4         5         6         7         8         9

 SYMBOLS

 FREQ.         0        11        44        41         3         0         0         0         1
```

Figure B-8 Hackensack Meadowlands Plan 1B

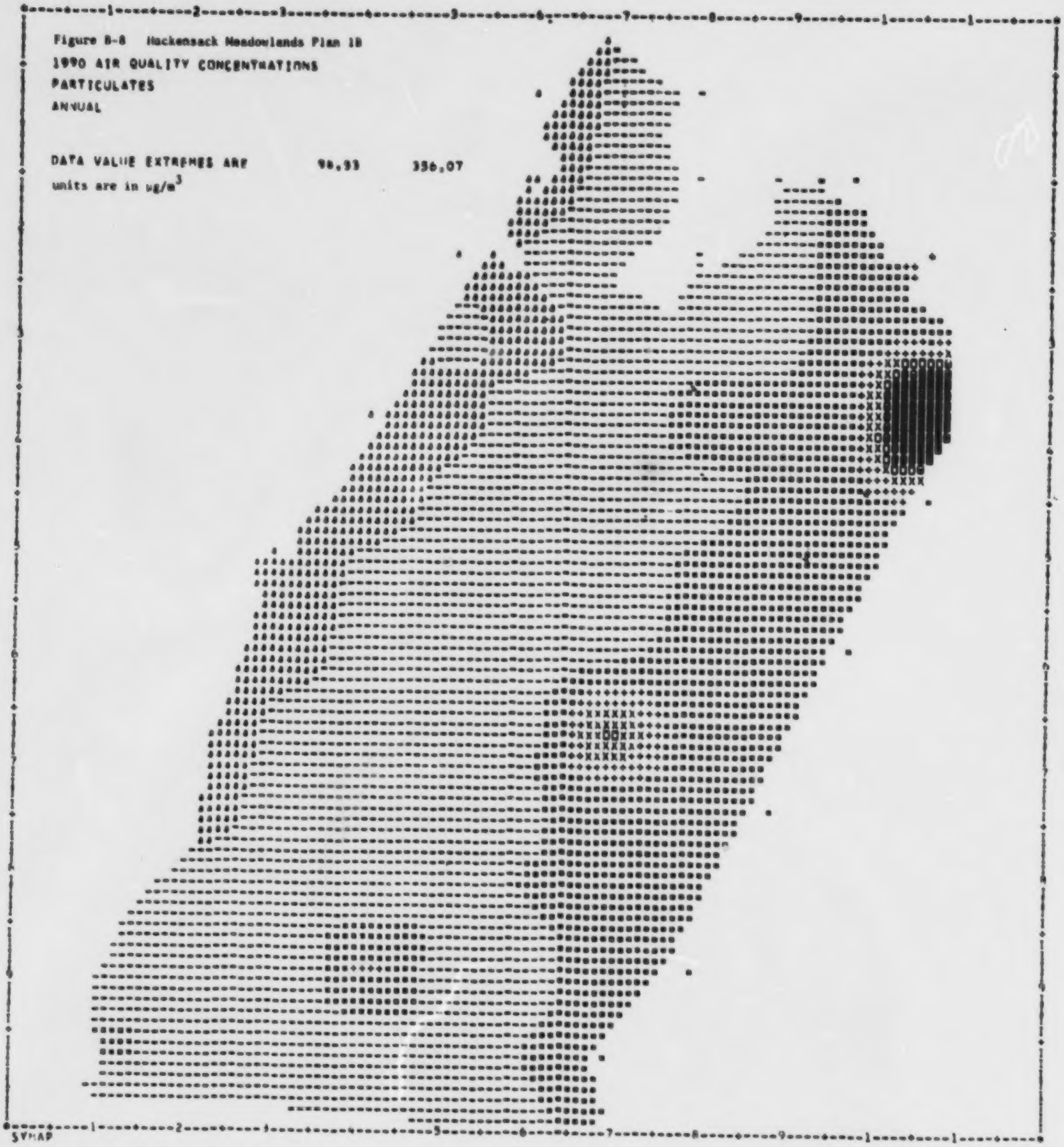
1990 AIR QUALITY CONCENTRATIONS

PARTICULATES

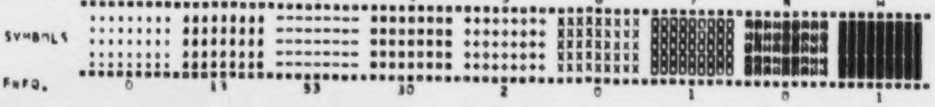
ANNUAL

DATA VALUE EXTREMES ARE 98.93 356.07

units are in $\mu g/m^3$



```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM    70.00    87.50    105.00   122.50   140.00   157.50   175.00   192.50   ABOVE
 MAXIMUM    87.50    105.00   122.50   140.00   157.50   175.00   192.50   210.00   210.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

            12.50    12.50    12.50    12.50    12.50    12.50    12.50    12.50

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL        1        2        3        4        5        6        7        8        H
```



```
 SYMBOLS
 FREQ.        0        13       53       30       2        0        1        0        1
```

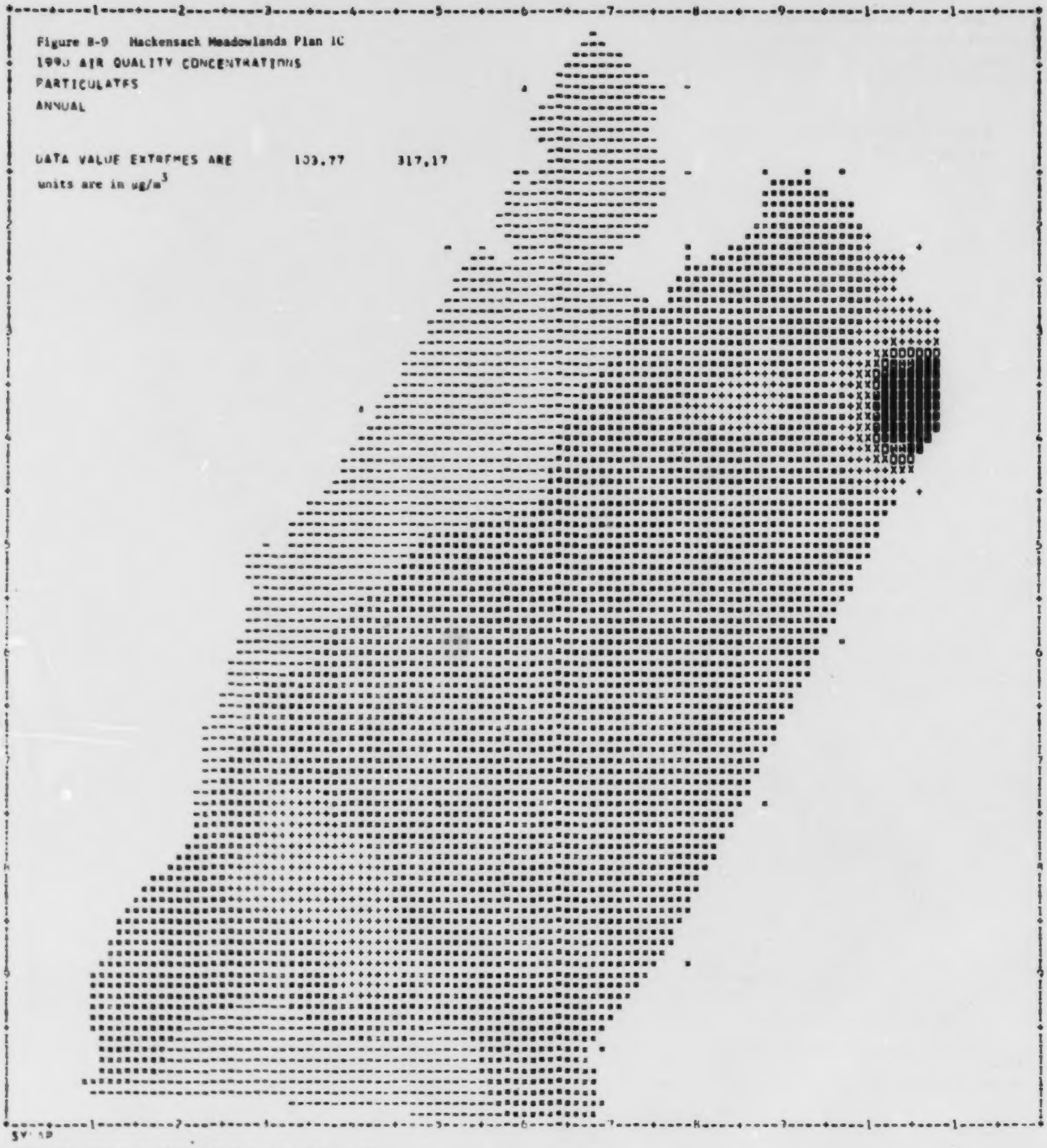


Figure 8-9 Hackensack Meadowlands Plan 1C
1990 AIR QUALITY CONCENTRATIONS
PARTICULATES
ANNUAL

DATA VALUE EXTREMES ARE 103.77 317.17
units are in $\mu g/m^3$

```
SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM      70.00      87.50     105.00     122.50     140.00     157.50     175.00     192.50     ABOVE
 MAXIMUM      87.50     105.00     122.50     140.00     157.50     175.00     192.50     210.00    210.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              12.50      12.50      12.50      12.50      12.50      12.50      12.50      12.50

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL         1          2          3          4          5          6          7          8          9

  SYMBOLS   .........  :::::::::  ---------  *********  +++++++++  XXXXXXXXX  OOOOOOOOO  HHHHHHHHH  █████████

  FREQ.         0          2         31         57          9          3          0          0          1
```

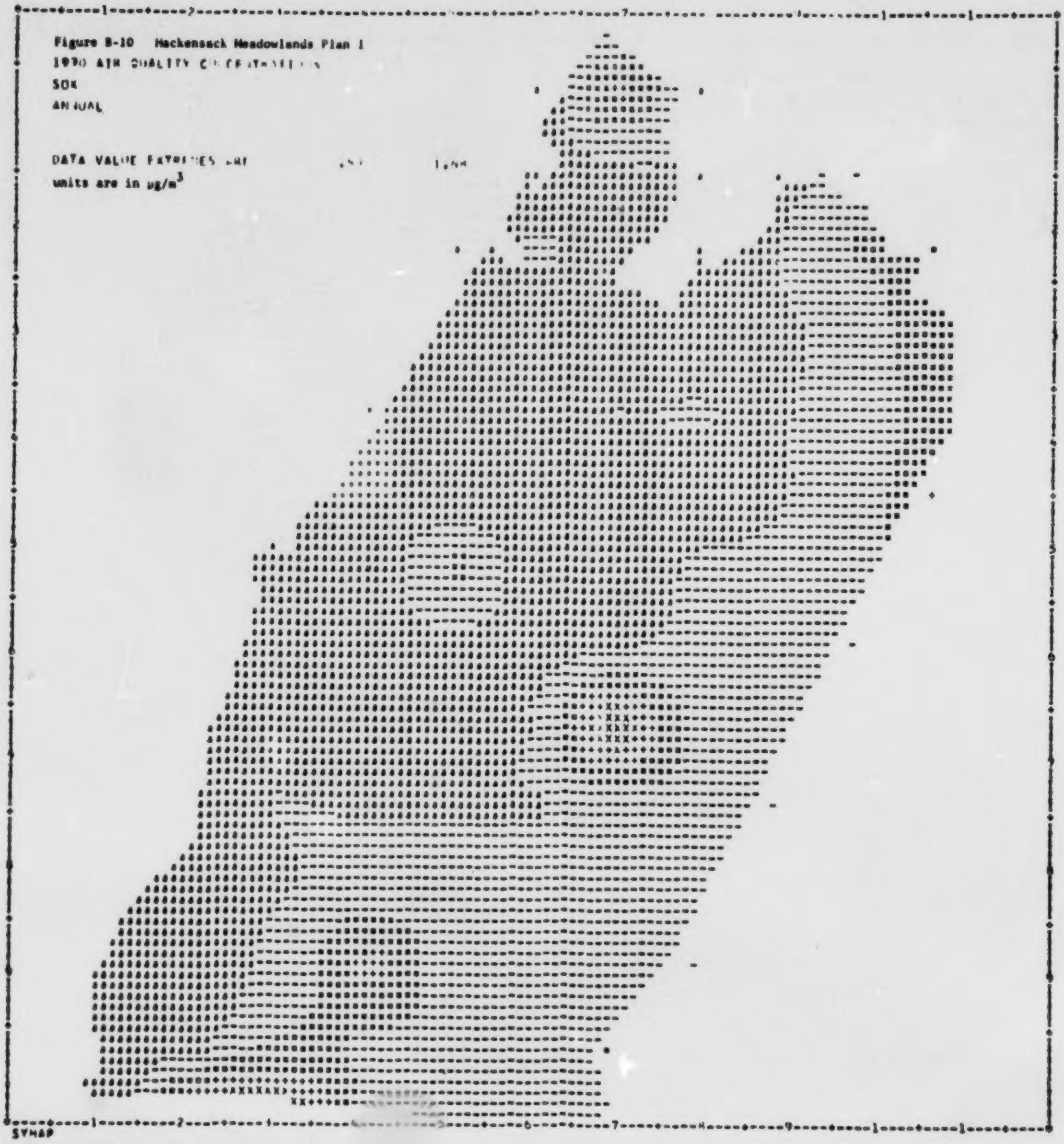


Figure B-10 Hackensack Meadowlands Plan I
1970 AIR QUALITY CONCENTRATIONS
SOX
ANNUAL

DATA VALUE EXTREMES ARE [illegible] [illegible]
units are in $\mu g/m^3$

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM      0.40      0.60      0.80      1.00      1.20      1.40      1.60      1.80      2.00      2.20
  MAXIMUM      0.60      0.80      1.00      1.20      1.40      1.60      1.80      2.00      2.20      2.40

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1         2         3         4         5         6         7         8         9        10

  SYMBOLS

  FREQ.          2        51        15         7         3         1         2         0         0         0
```

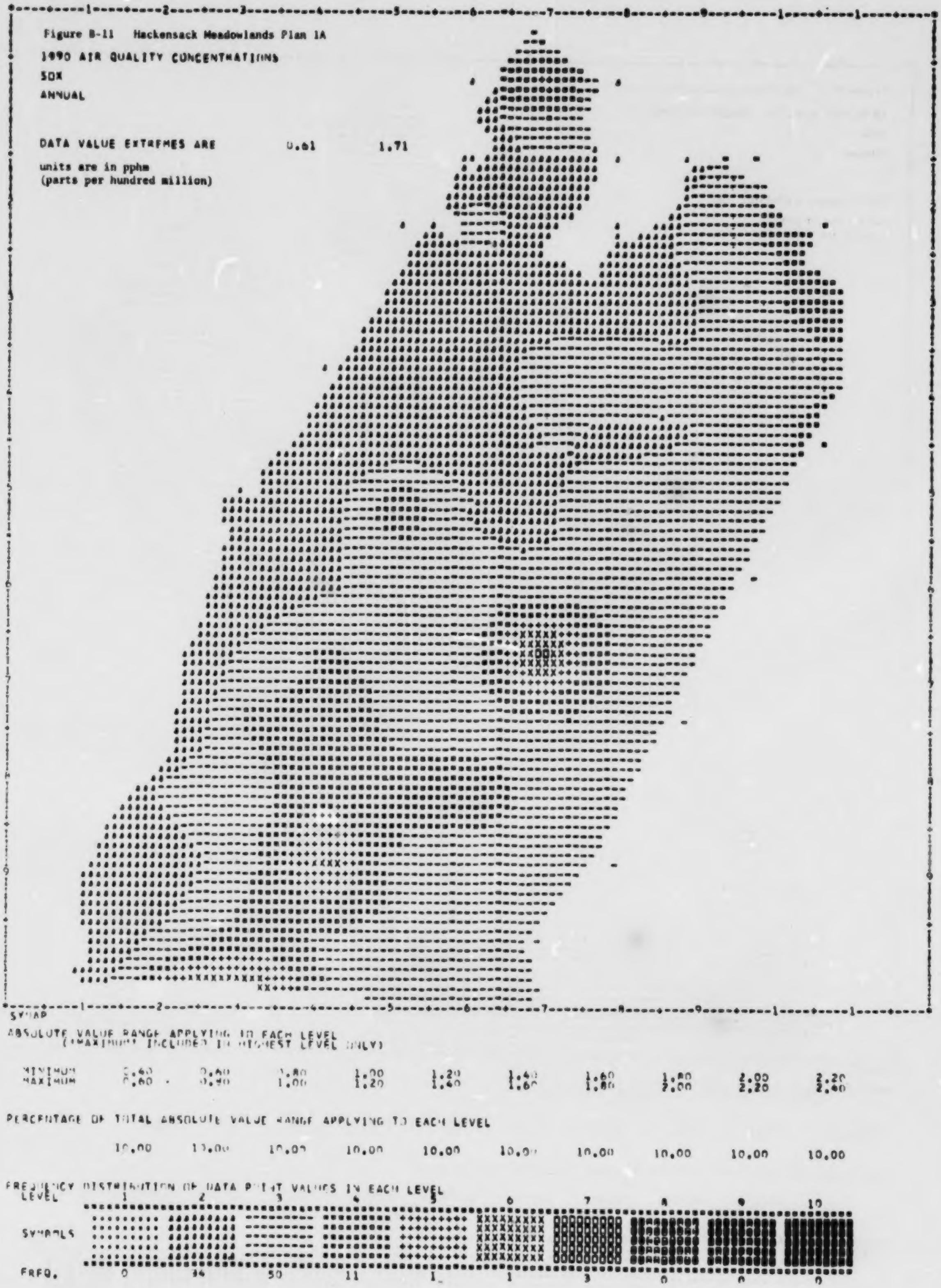


Figure B-11 Hackensack Meadowlands Plan 1A

1990 AIR QUALITY CONCENTRATIONS

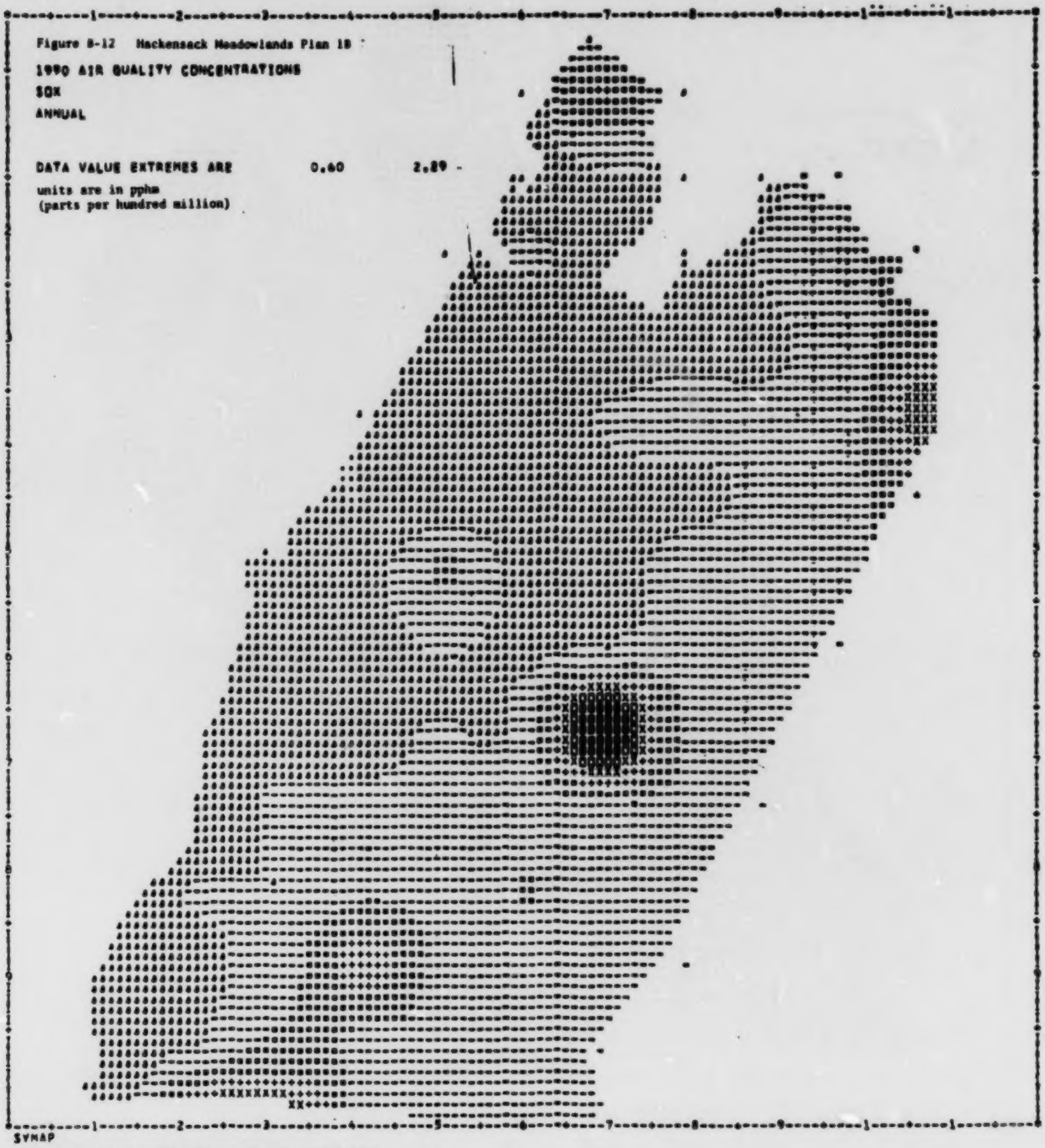
SOX

ANNUAL

DATA VALUE EXTREMES ARE 0.61 1.71

units are in pphm
(parts per hundred million)

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM     0.40     0.60     0.80     1.00     1.20     1.40     1.60     1.80     2.00     2.20
  MAXIMUM     0.60 .   0.80     1.00     1.20     1.40     1.60     1.80     2.00     2.20     2.40

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL       1        2        3        4        5        6        7        8        9        10

  SYMBOLS

  FREQ.       0        34       50       11       1_       1        3        0        0        0
```



```
Figure 8-12   Hackensack Meadowlands Plan 1B

1990 AIR QUALITY CONCENTRATIONS
SOX
ANNUAL

DATA VALUE EXTREMES ARE          0.60          2.89

units are in pphm
(parts per hundred million)
```

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM     0.40     0.60     0.80     1.00     1.20     1.40     1.60     1.80     2.00     2.20
  MAXIMUM     0.60     0.80     1.00     1.20     1.40     1.60     1.80     2.00     2.20     2.40

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL        1        2        3        4        5        6        7        8        9       10

  SYMBOLS

  FREQ.        1       37       50        5        3        1        2        0        0        1
```

Figure B-13 Hackensack Meadowlands Plan 1C

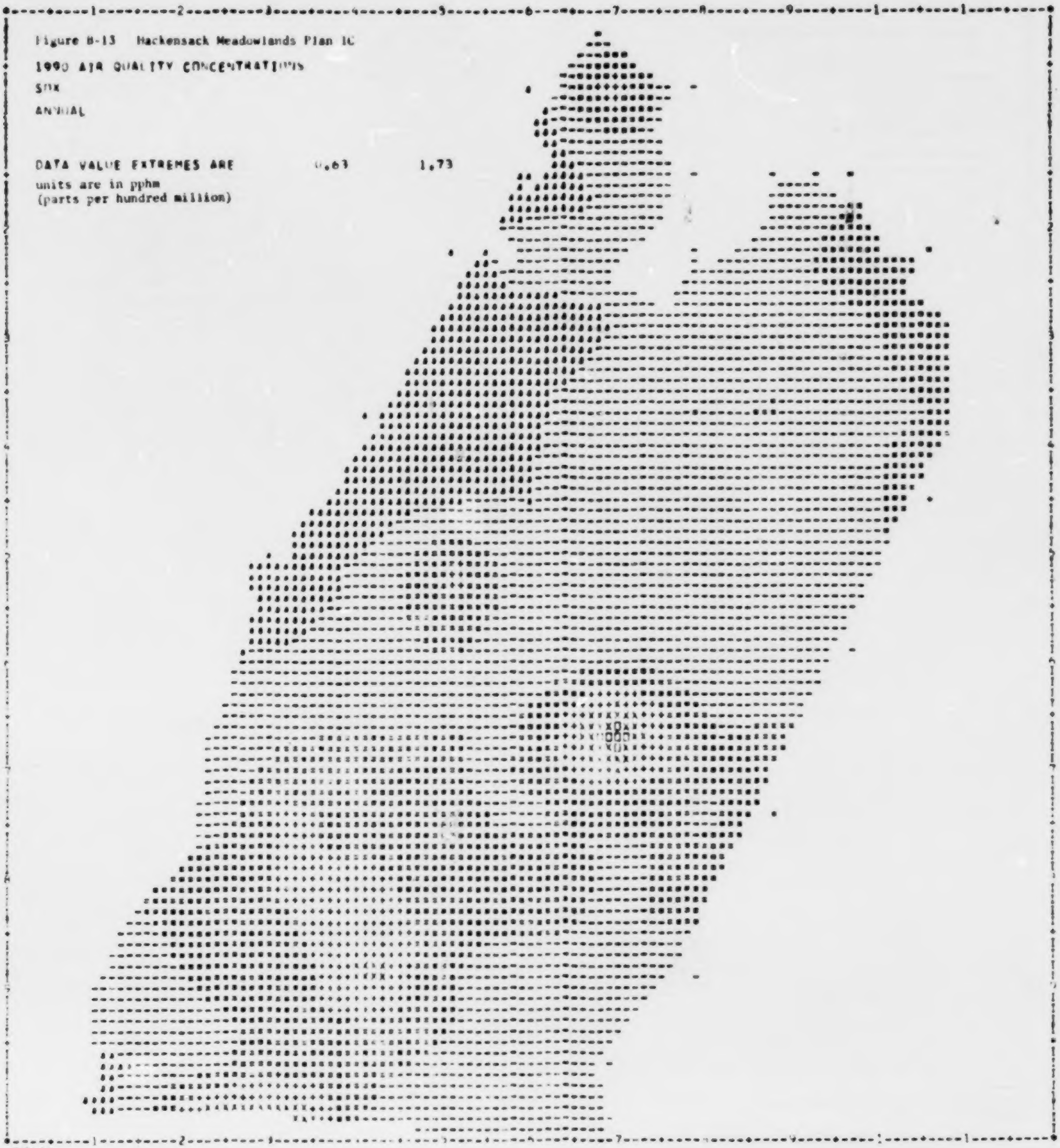
1990 AIR QUALITY CONCENTRATIONS

SOX

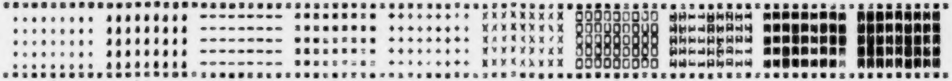
ANNUAL

DATA VALUE EXTREMES ARE 0.63 1.73

units are in pphm
(parts per hundred million)



```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM      .40      .60      .80     1.00     1.20     1.40     1.60     1.80     2.00     2.20
MAXIMUM      .60      .80     1.00     1.20     1.40     1.60     1.80     2.00     2.20     2.40

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

           10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL       1        2        3        4        5        6        7        8        9       10
```



```
FREQ.         0       14       51       25        6        1        3        0        0        0
```

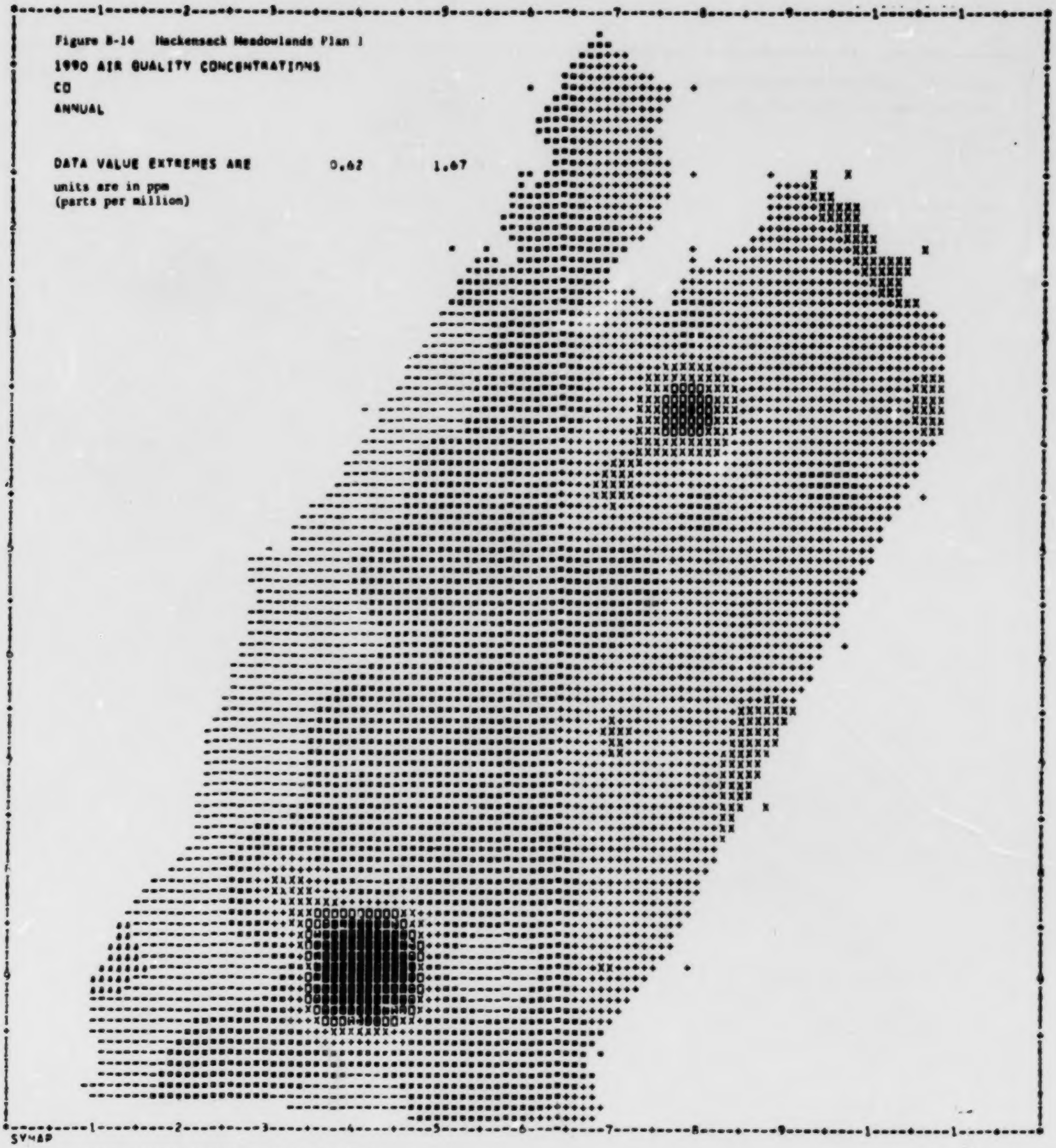


Figure B-14 Hackensack Meadowlands Plan 1

1990 AIR QUALITY CONCENTRATIONS

CO

ANNUAL

DATA VALUE EXTREMES ARE 0.62 1.67

units are in ppm
(parts per million)

SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

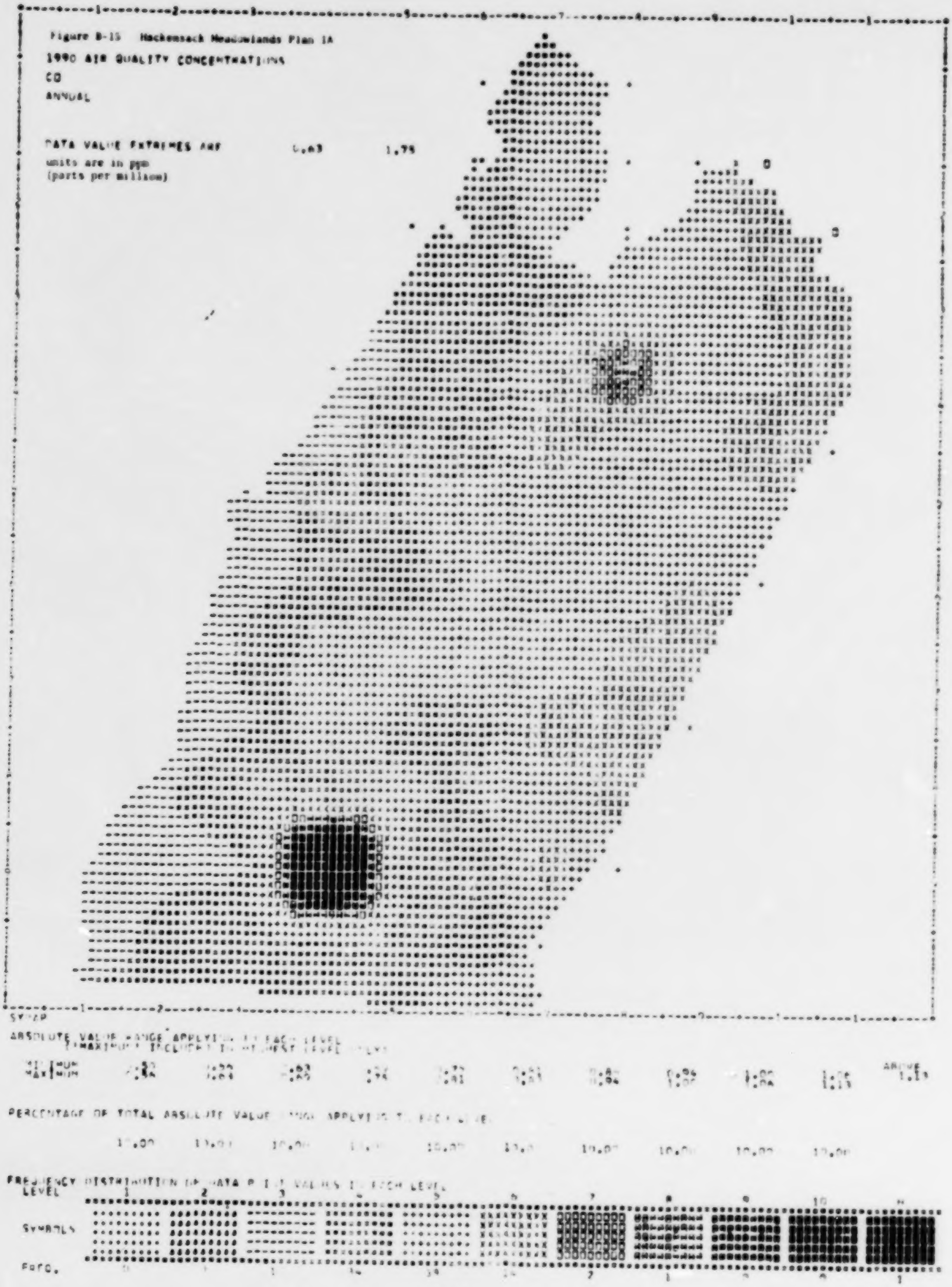
MINIMUM	0.50	0.56	0.63	0.69	0.75	0.81	0.88	0.94	1.00	1.06	ABOVE 1.13
MAXIMUM	0.56	0.63	0.69	0.75	0.81	0.88	0.94	1.00	1.06	1.13	

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10	H
SYMBOLS	·	'	-	●	+	X	O	■	■	■	■
FREQ.	0	1	19	38	31	9	0	1	0	0	1



SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
(MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)
MINIMUM
MAXIMUM
ABOVE
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
10.00
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
LEVEL
1
2
3
4
5
6
7
8
9
10
H
SYMBOLS
FREQ.

Figure B-15 Hackensack Meadowlands Plan 1A
1990 AIR QUALITY CONCENTRATIONS
CO
ANNUAL

DATA VALUE EXTREMES ARE 0.63 1.75
units are in ppm
(parts per million)

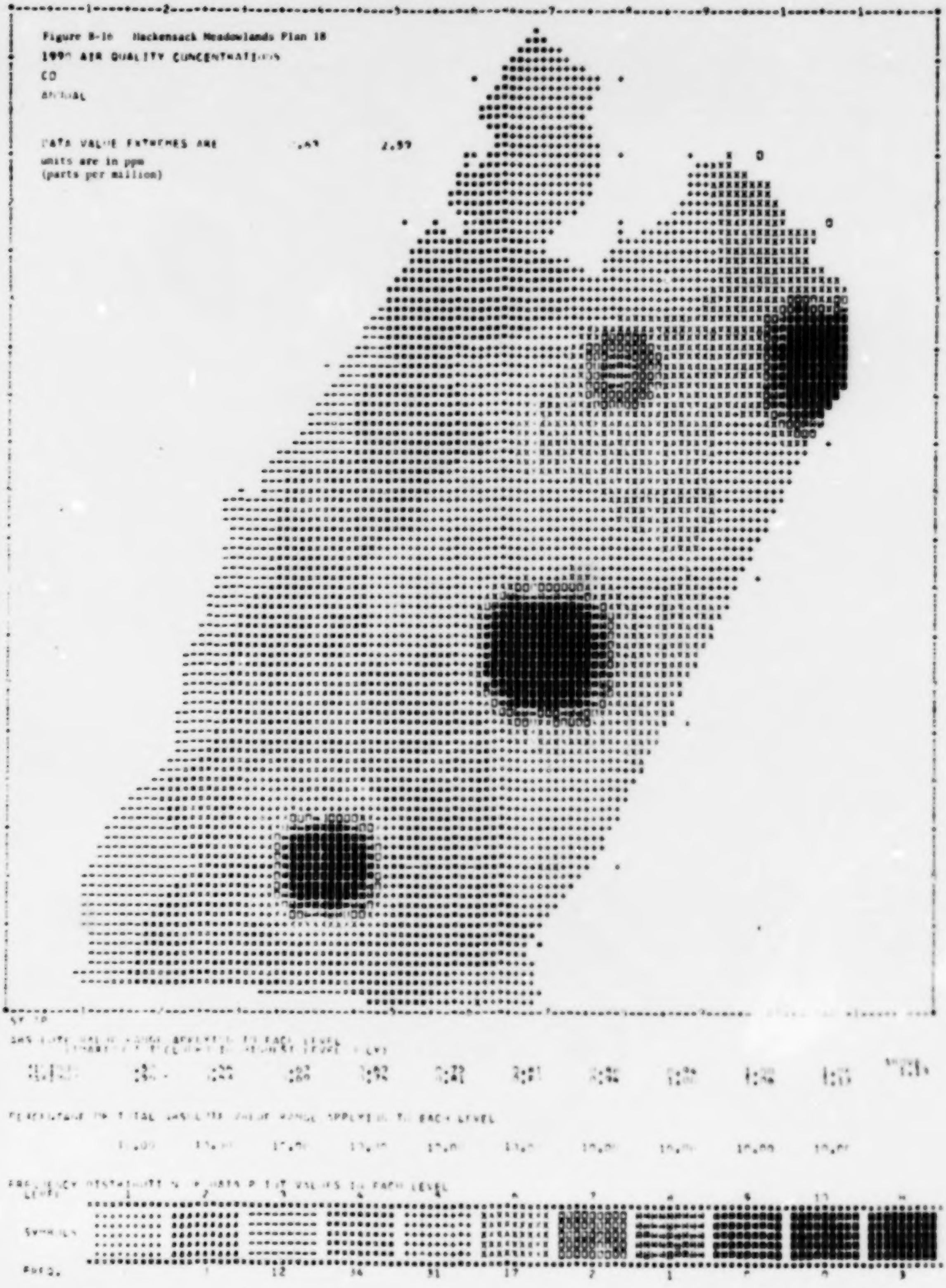


Figure 8-16 Hackensack Meadowlands Plan 18

199? AIR QUALITY CONCENTRATIONS

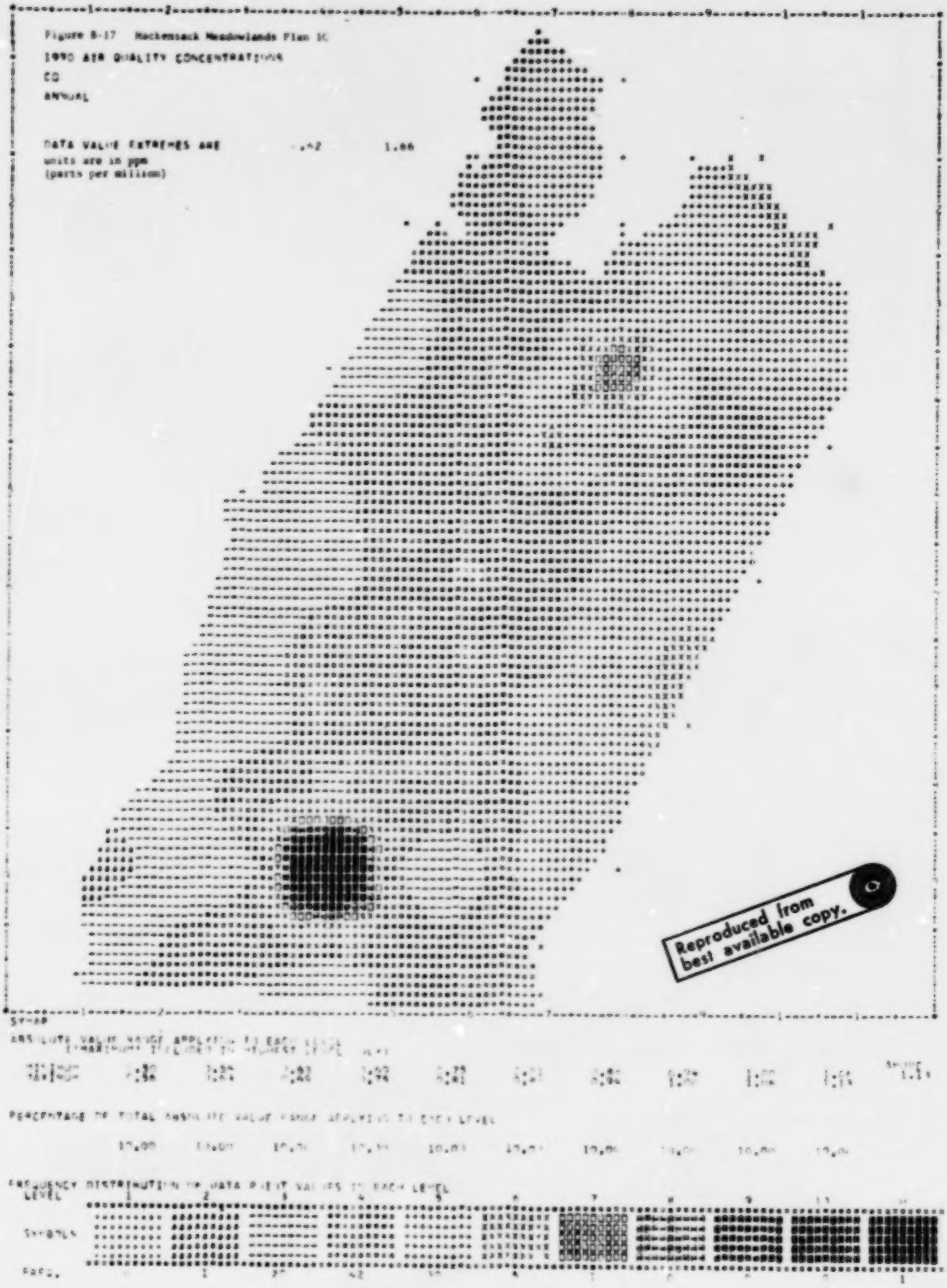
CO

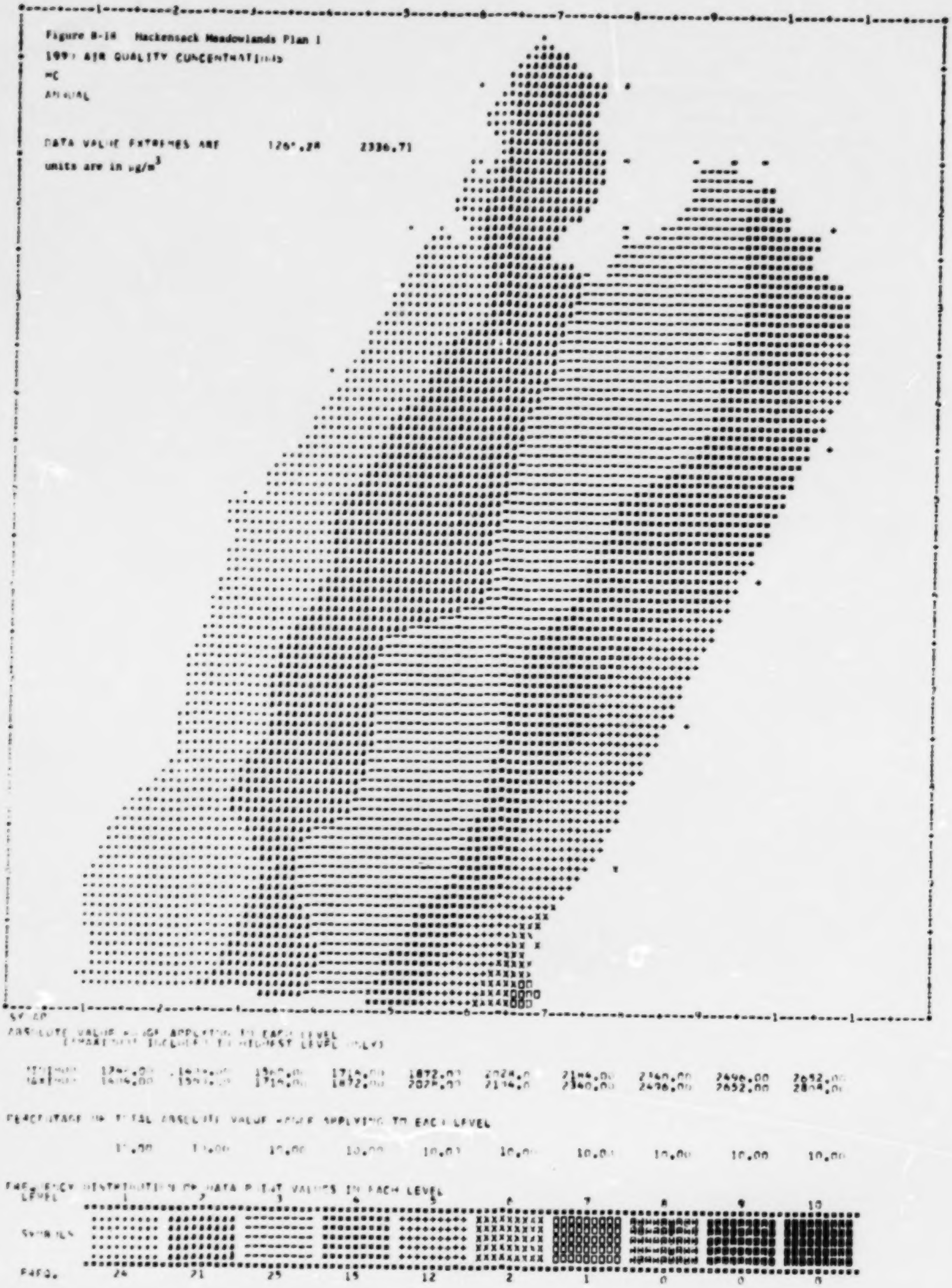
ANNUAL

DATA VALUE EXTREMES ARE .63 2.59

units are in ppm
(parts per million)

LEVEL
1
2
3
4
5
6
7
8
9
10
SYMBOLS
FREQ.
1
12
36
31
17
2
1





```
Figure 8-14   Hackensack Meadowlands Plan I
1990 AIR QUALITY CONCENTRATIONS
HC
ANNUAL

DATA VALUE EXTREMES ARE      126[illegible].28     2336.71
units are in µg/m3

SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM   1248.00   1404.00   1560.00   1716.00   1872.00   2028.0    2184.00   2340.00   2496.00   2652.00
MAXIMUM   1404.00   1560.00   1716.00   1872.00   2028.00   2184.0    2340.00   2496.00   2652.00   2808.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

          10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
LEVEL       1         2         3         4         5         6         7         8         9        10

SYMBOLS

FREQ.      24        21        25        15        12         2         1         0         0         0
```

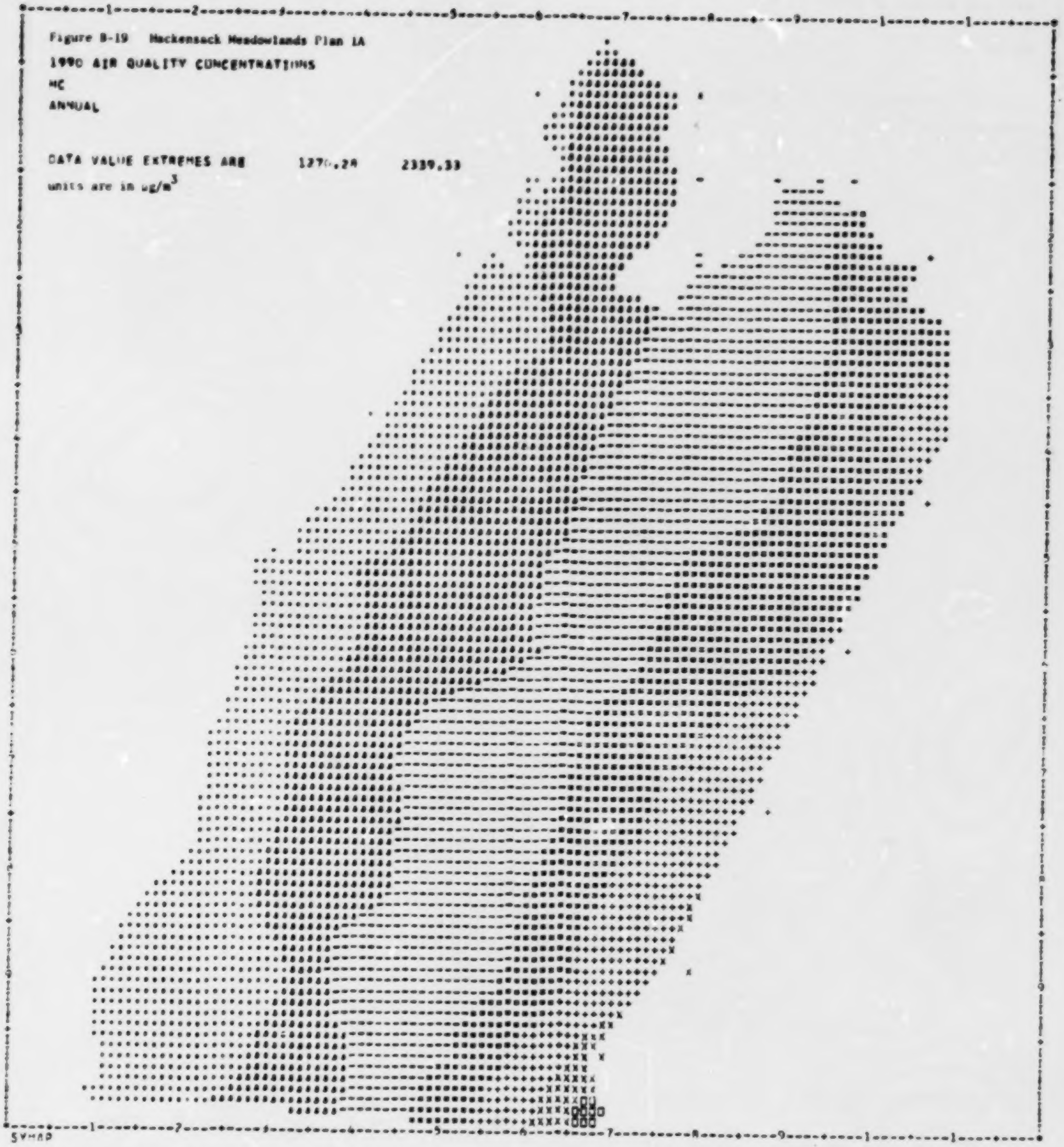
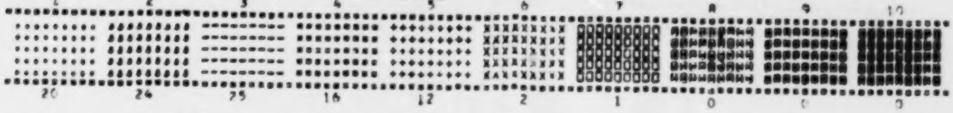


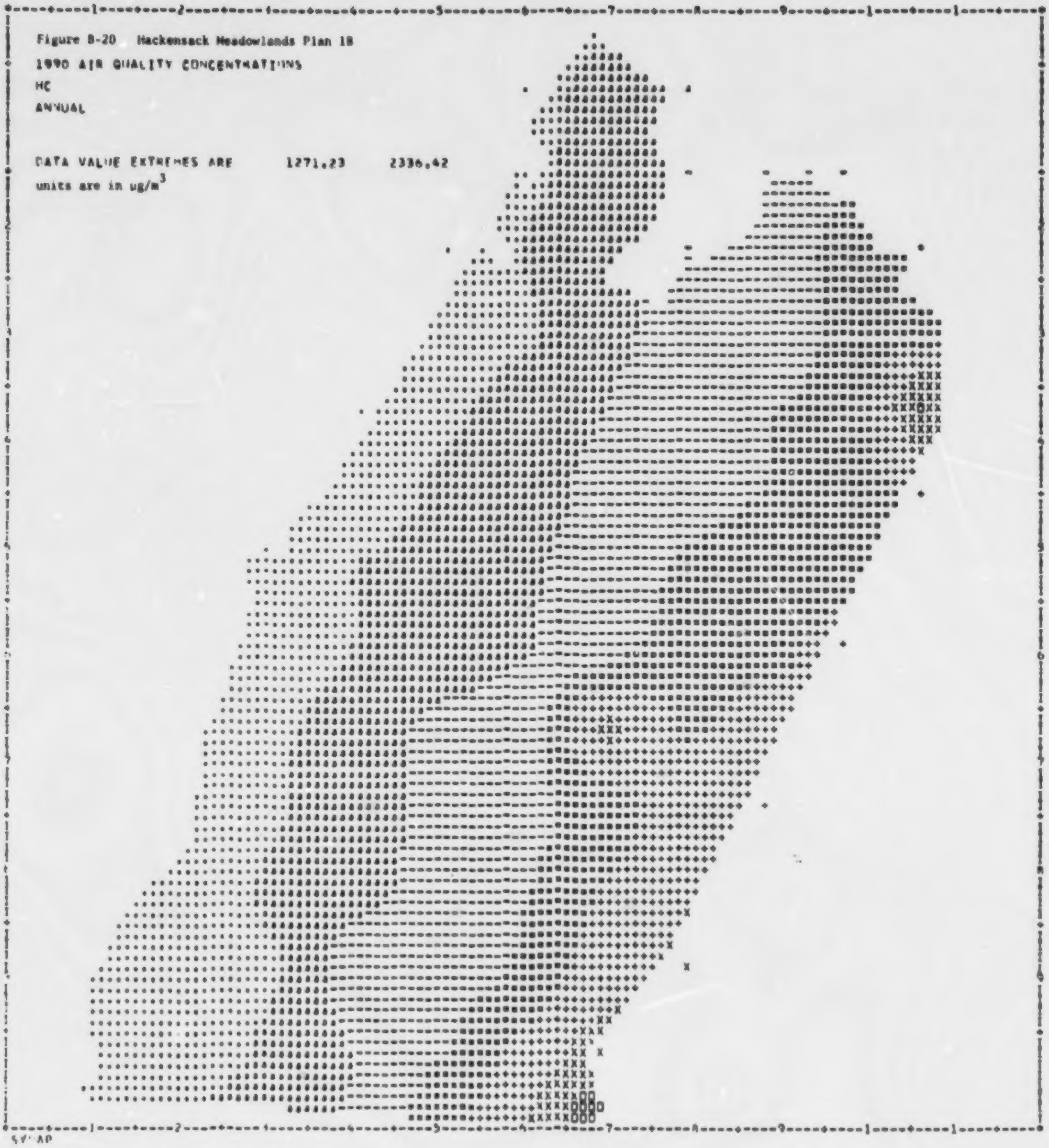
Figure 8-19 Hackensack Meadowlands Plan 1A
1990 AIR QUALITY CONCENTRATIONS
HC
ANNUAL
DATA VALUE EXTREMES ARE 1270.28 2339.33
units are in ug/m3
SYMAP

```
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (*MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM   1248.00   1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00
 MAXIMUM   1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00   2808.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

           10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL       1         2         3         4         5         6         7         8         9         10
```



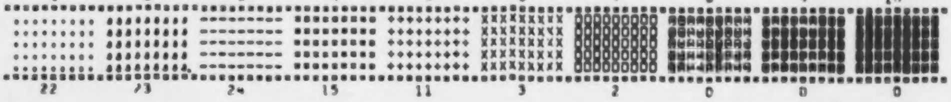
```
 SYMBOLS

 FREQ.       20        24        25        16        12        2         1         0         0         0
```

```
Figure B-20   Hackensack Meadowlands Plan 1B
1990 AIR QUALITY CONCENTRATIONS
HC
ANNUAL

DATA VALUE EXTREMES ARE       1271.23     2336.42
units are in ug/m³
```



```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (*MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM    1248.00   1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00
  MAXIMUM    1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00   2808.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL        1         2         3         4         5         6         7         8         9         10
```

SYMBOLS



```
  FREQ.       22        23        24        15        11         3         2         0         0         0
```

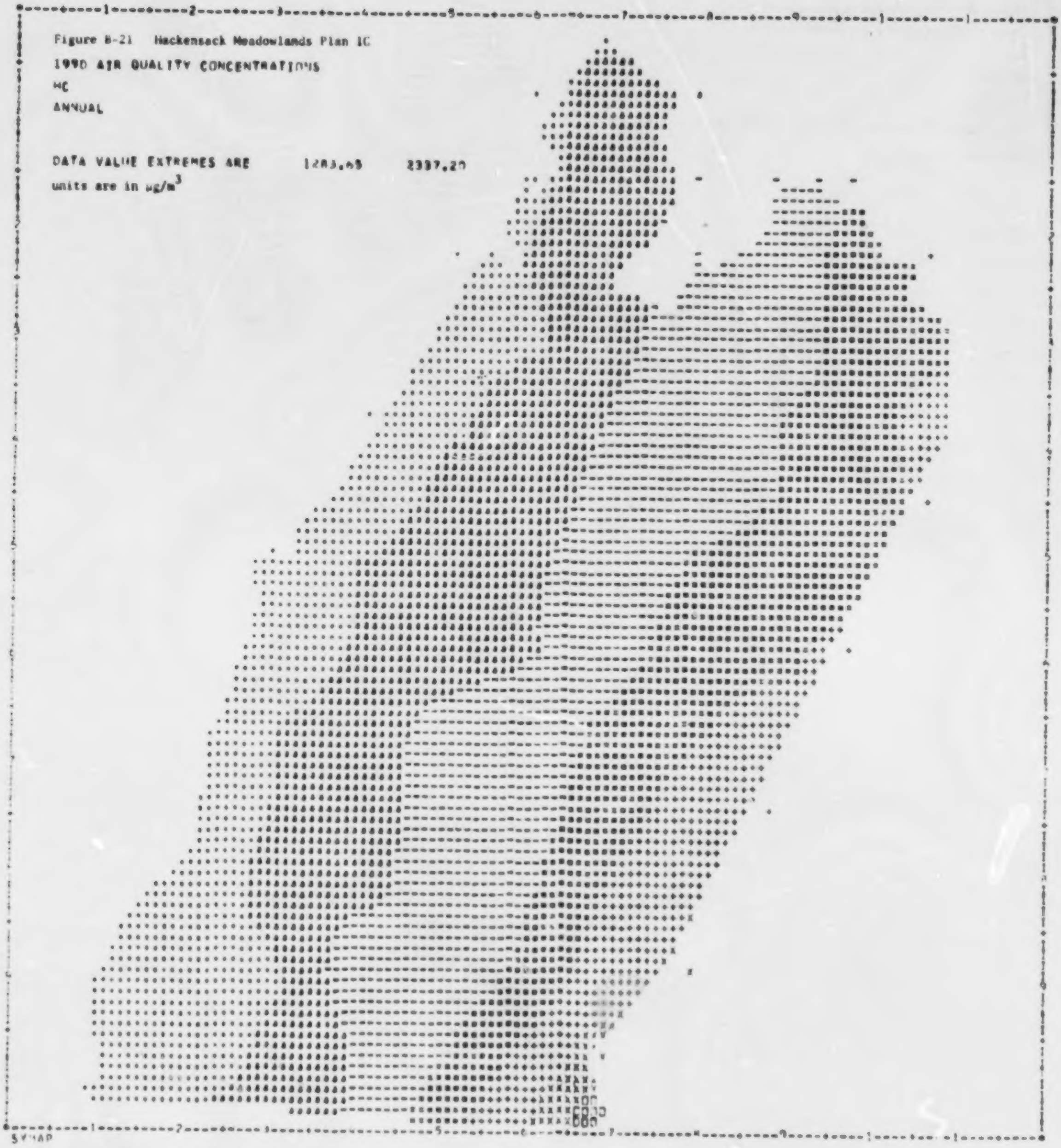


Figure B-21 Hackensack Meadowlands Plan IC

1990 AIR QUALITY CONCENTRATIONS

HC

ANNUAL

DATA VALUE EXTREMES ARE 1283.65 2337.20

units are in $\mu g/m^3$

```
SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM   1248.00   1404.00   1560.00   1716.00   1872.00   2028.0    2184.00   2340.00   2496.00   [illegible]
 MAXIMUM   1404.00   1560.00   1716.00   1872.00   2028.00   2184.0    2340.00   2496.00   2652.00   [illegible]

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

           10.00     10.00     10.00     10.00     10.00     10.0      10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL       1         2         3         4         5         6         7         8         9        10

 SYMBOLS

 FREQ.      14        25        26        19        12         2         1         0    [illegible] [illegible]
```

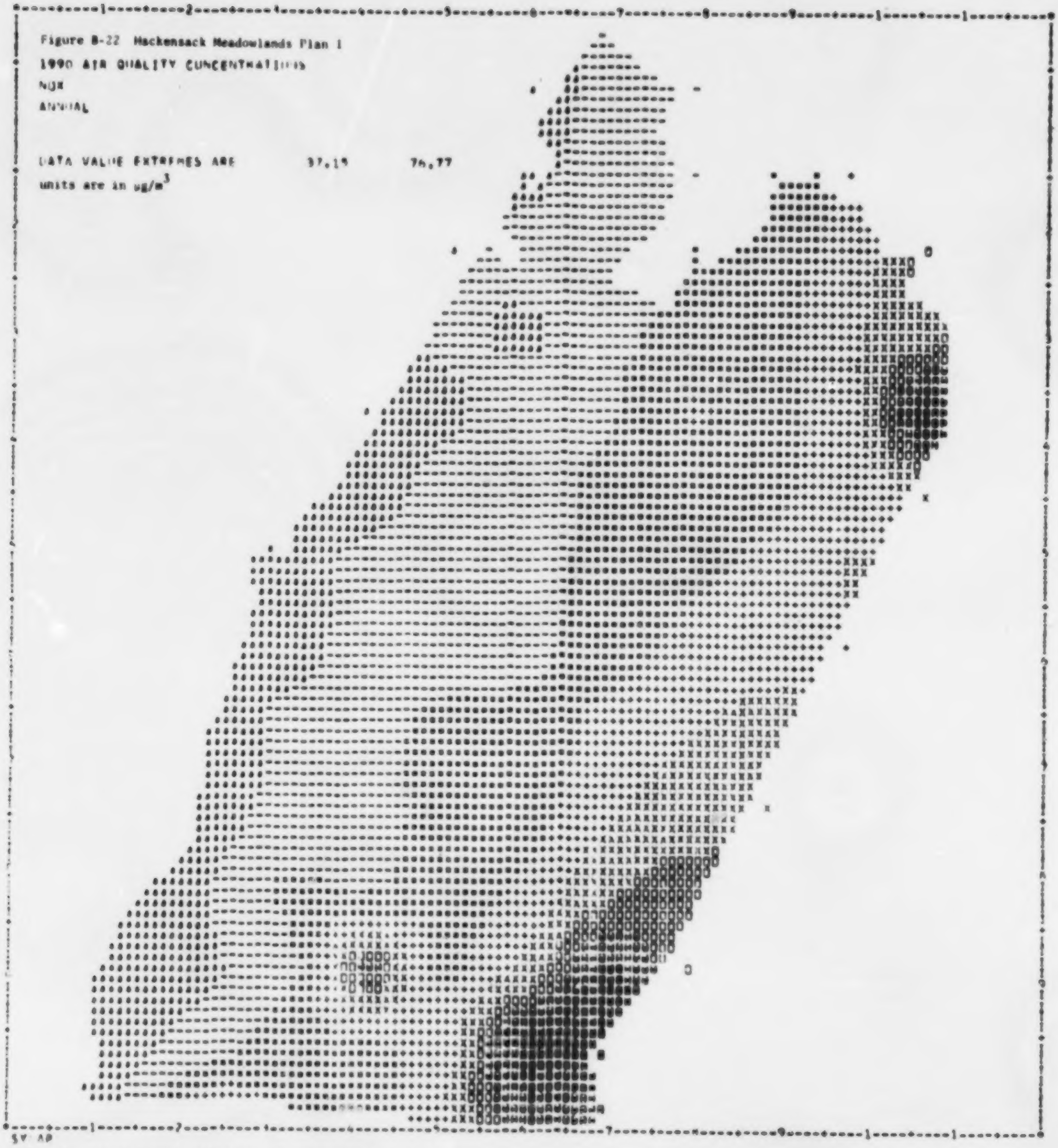


Figure B-22 Hackensack Meadowlands Plan 1

1990 AIR QUALITY CONCENTRATIONS

NOX

ANNUAL

DATA VALUE EXTREMES ARE 37.15 76.77

units are in $\mu g/m^3$

SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
(MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	30.00	35.00	40.00	45.00	50.00	55.00	60.00	65.00	70.00	75.00
MAXIMUM	35.00	40.00	45.00	50.00	55.00	60.00	65.00	70.00	75.00	80.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10
SYMBOLS	·········	⁘⁘⁘⁘⁘⁘⁘⁘⁘	–––––––––	■■■■■■■■■	+++++++++	XXXXXXXXX	OOOOOOOOO	▨▨▨▨▨▨▨▨▨	▩▩▩▩▩▩▩▩▩	█████████
FREQ.	1	17	25	23	16	9	4	2	2	2

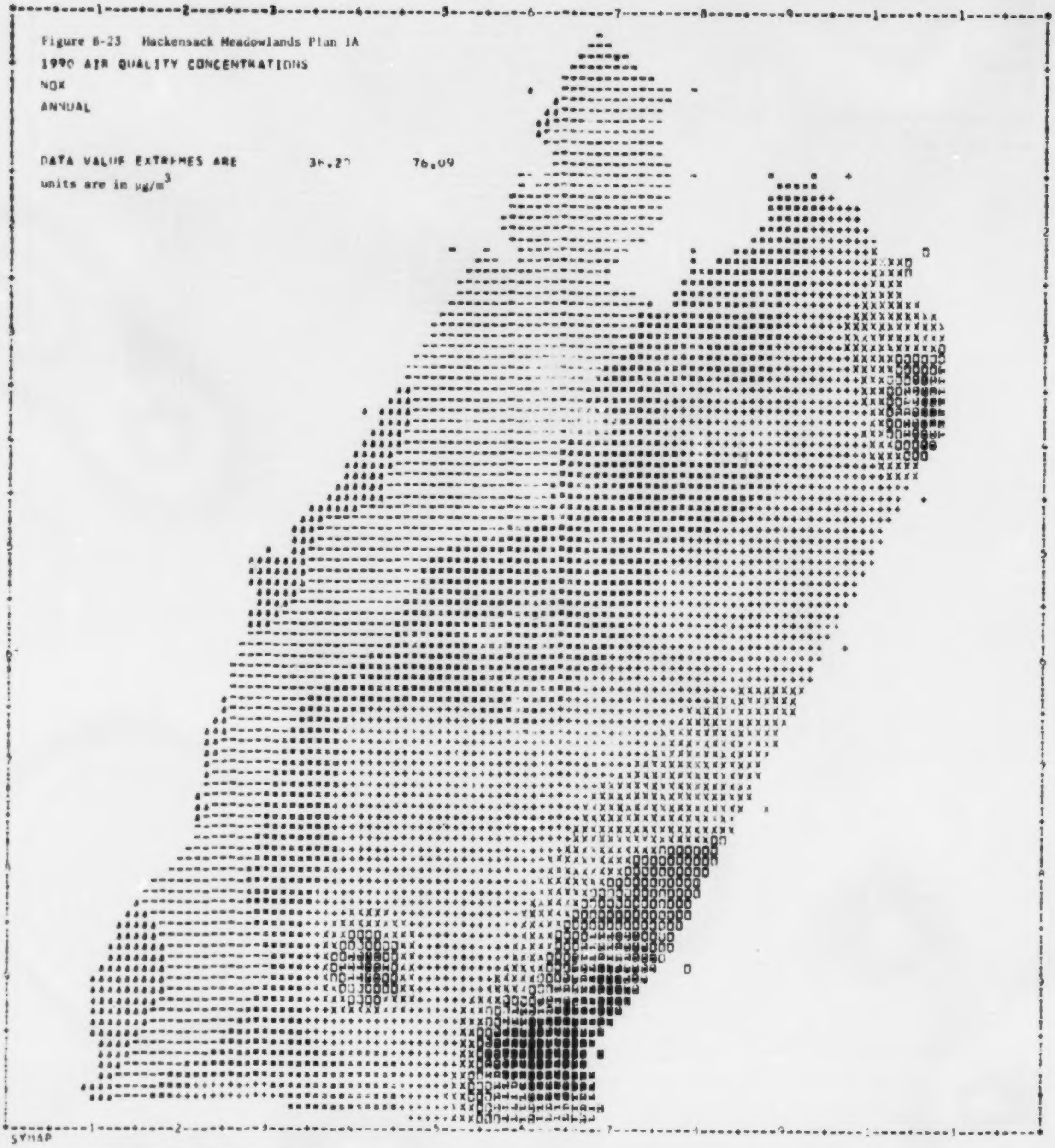


Figure B-23 Hackensack Meadowlands Plan 1A

1990 AIR QUALITY CONCENTRATIONS

NOX

ANNUAL

DATA VALUE EXTREMES ARE 36.20 76.09

units are in $\mu g/m^3$

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM     30.00    35.00    40.00    45.00    50.00    55.00     60.00    65.00    70.00    75.00
  MAXIMUM     35.00    40.00    45.00    50.00    55.00    60.00     65.00    70.00    75.00    80.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              10.00    10.00    10.00    10.00    10.00    10.00     10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL         1        2        3        4        5        6         7        8        9       10

  SYMBOLS    ........ ######## -------- ======== ++++++++ XXXXXXXX  OOOOOOOO HHHHHHHH ■■■■■■■■ ■■■■■■■■

  FREQ.         0        3       24       13       25        -         6        2        2        2
```

Figure B-24 Hackensack Meadowlands Plan 1B

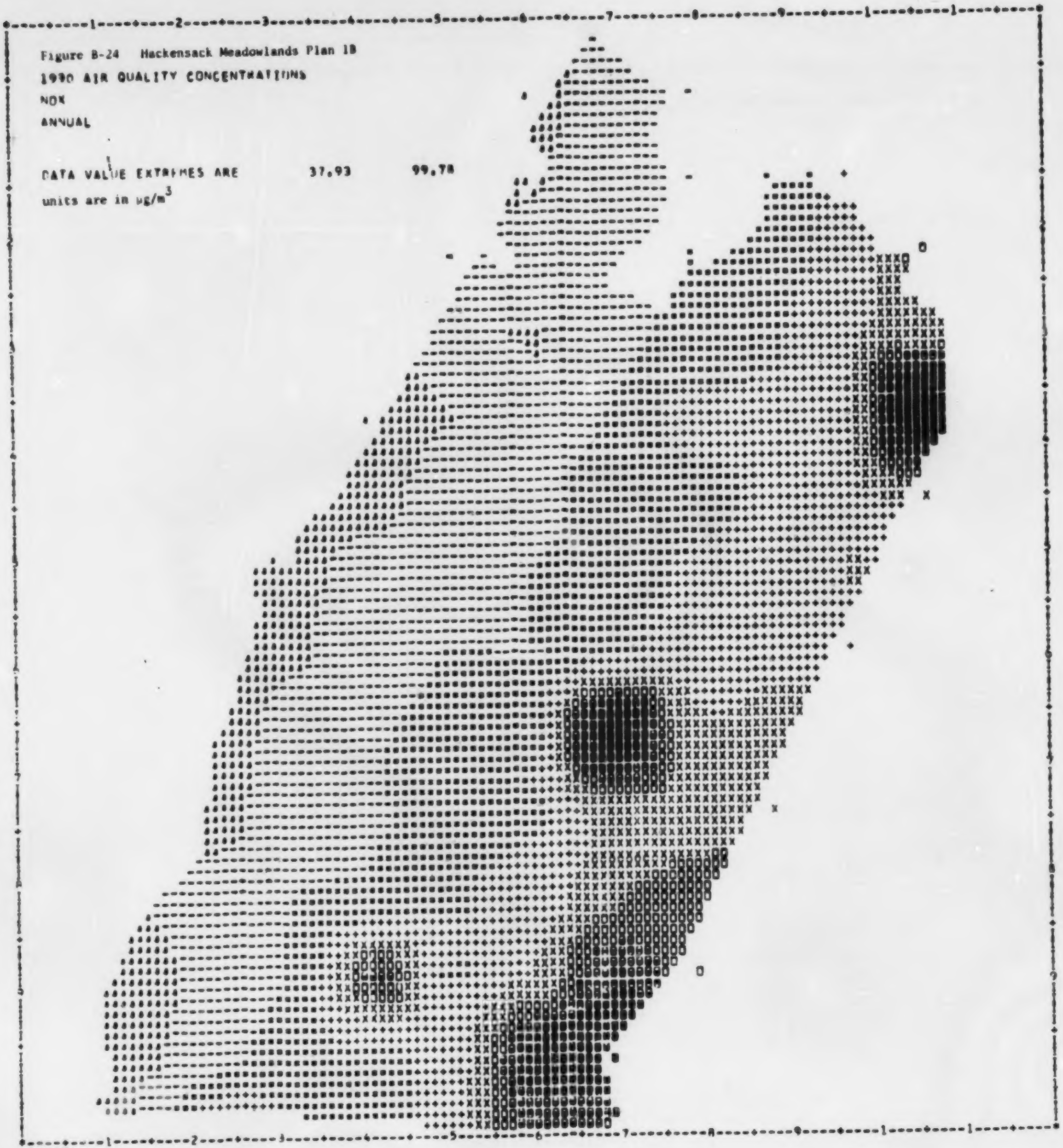
1990 AIR QUALITY CONCENTRATIONS

NOX

ANNUAL

DATA VALUE EXTREMES ARE 37.93 99.78

units are in $\mu g/m^3$



SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
(MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	30.00	35.00	40.00	45.00	50.00	55.00	60.00	65.00	70.00	75.00	ABOVE 80.00
MAXIMUM	35.00	40.00	45.00	50.00	55.00	60.00	65.00	70.00	75.00	80.00	

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10	H
SYMBOLS	·	▪	—	■	+	X	0	▨	▩	▮	█
FREQ.	0	13	24	25	16	10	5	2	2	1	2

Figure B-25 Hackensack Meadowlands Plan 1C

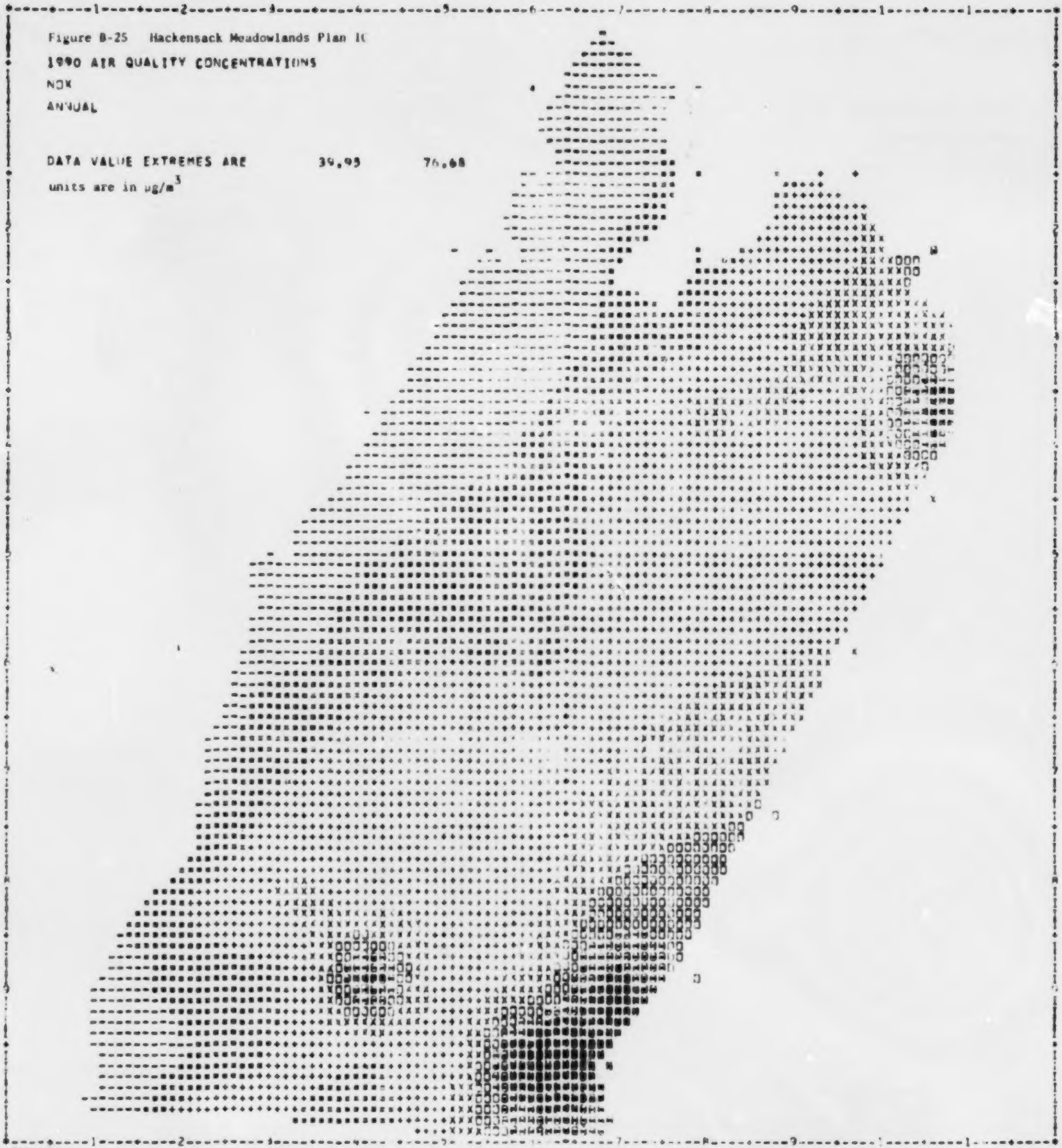
1990 AIR QUALITY CONCENTRATIONS

NOX

ANNUAL

DATA VALUE EXTREMES ARE 39.95 76.68

units are in $\mu g/m^3$



```
SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM     30.00     35.00     40.00     45.00     50.00     55.00     60.00     65.00     70.00     75.00
  MAXIMUM     35.00     40.00     45.00     50.00     55.00     60.00     65.00     70.00     75.00     80.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL         1         2         3         4         5         6         7         8         9        10

  FREQ.         0         1        21   [illegible]  [illegible]   13   [illegible]    2         3   [illegible]
```

Figure B-26 Hackensack Meadowlands Plan 1

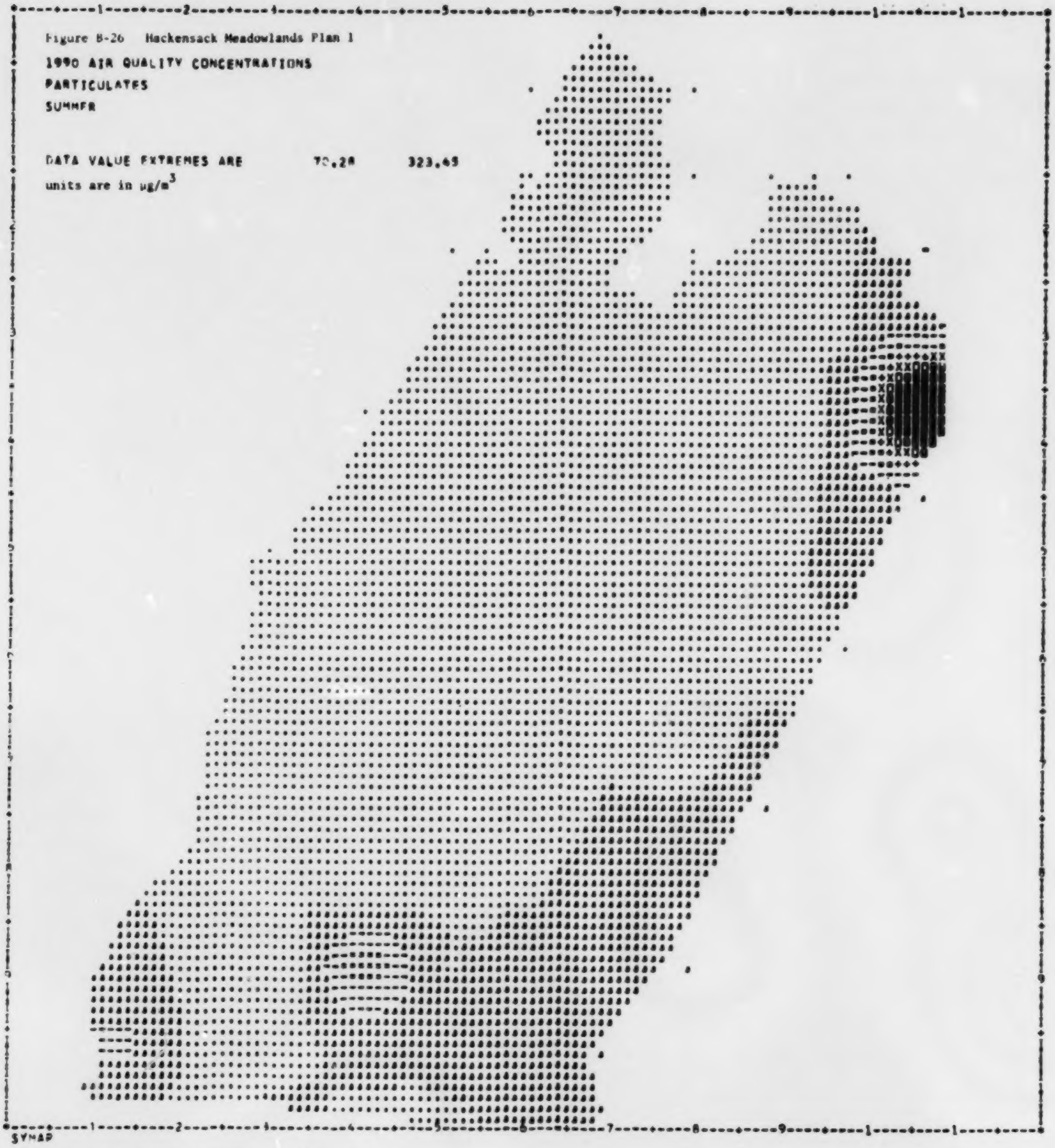
1990 AIR QUALITY CONCENTRATIONS

PARTICULATES

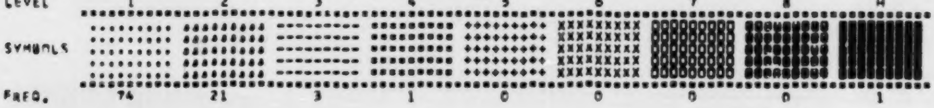
SUMMER

DATA VALUE EXTREMES ARE 70.28 323.45

units are in $\mu g/m^3$



```
SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM      70.00     87.50    105.00    122.50    140.00    157.50    175.00    192.50     ABOVE
 MAXIMUM      87.50    105.00    122.50    140.00    157.50    175.00    192.50    210.00    210.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              12.50     12.50     12.50     12.50     12.50     12.50     12.50     12.50

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL          1         2         3         4         5         6         7         8         H
```



```
 FREQ.         74        21         3         1         0         0         0         0         1
```

Figure B-27 Hackensack Meadowlands Plan IA

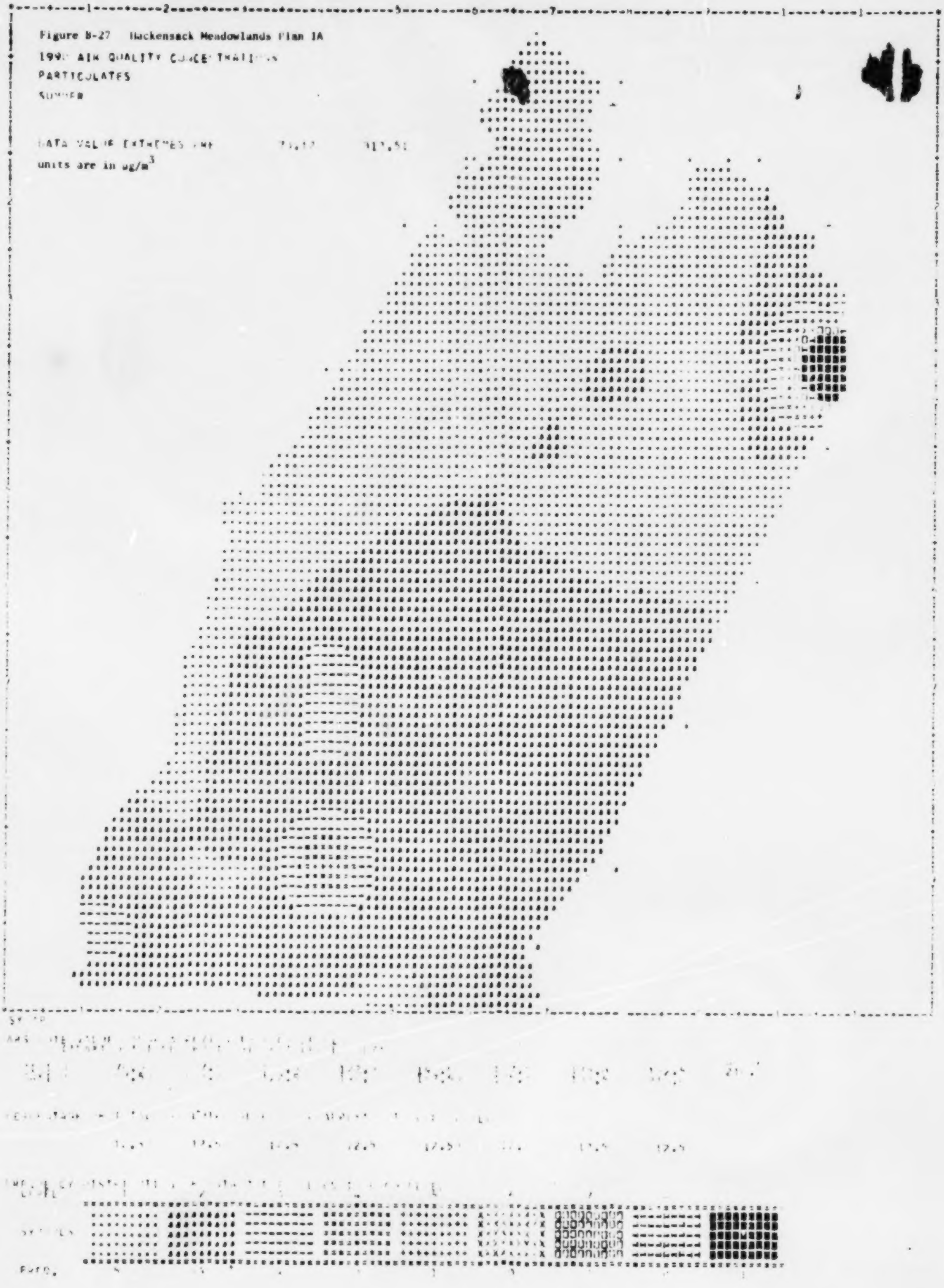
1990 AIR QUALITY CONCENTRATIONS

PARTICULATES

SUMMER

DATA VALUE EXTREMES ARE 73.12 313.51

units are in ug/m^3



SYMBOLS
LEVEL 1 2 3 4 5 6 7 8 9
12.5 12.5 12.5 12.5 12.5 12.5 12.5
FREQ.

Figure B-28 Hackensack Meadowlands Plan 1B

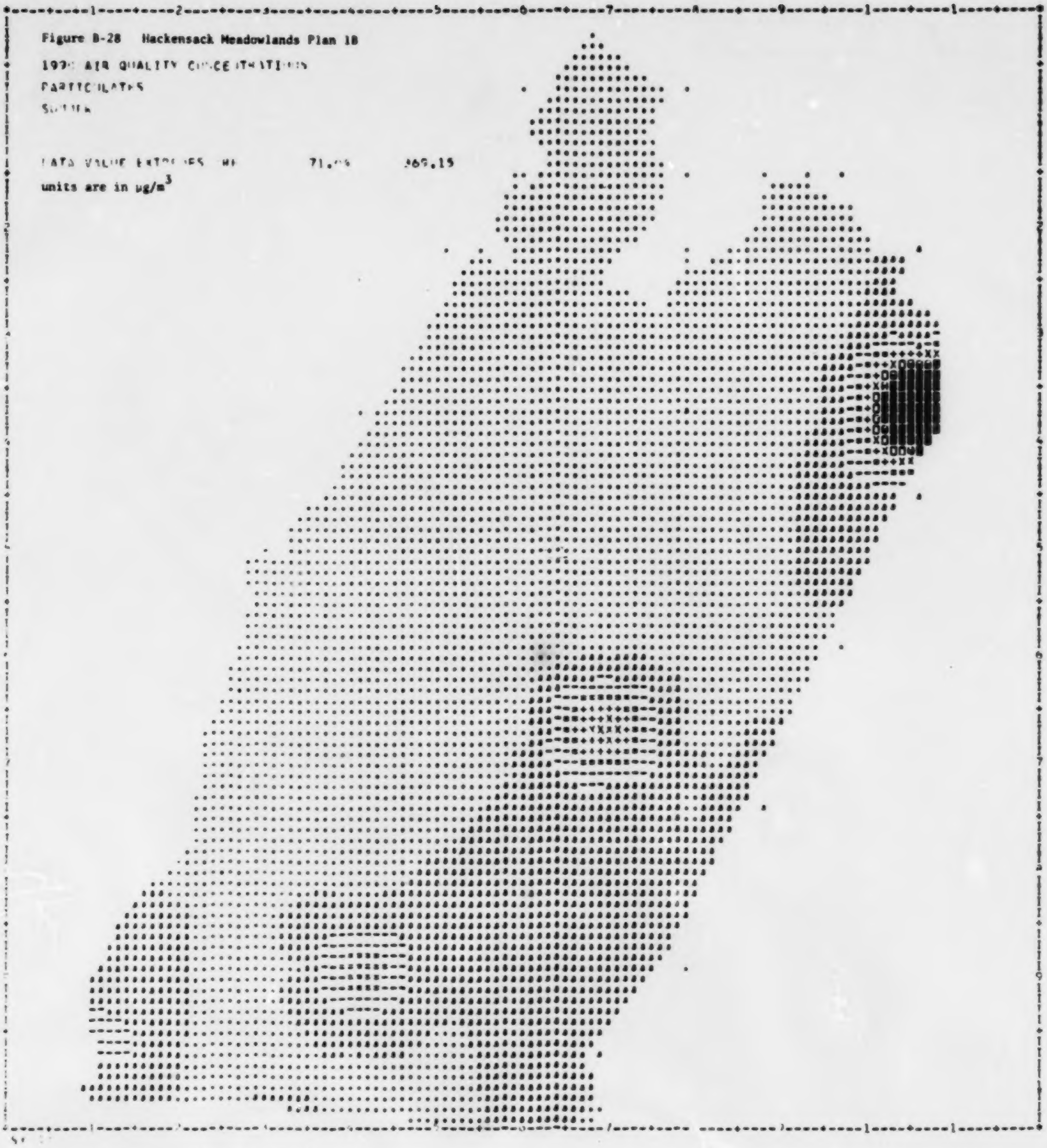
1990 AIR QUALITY CONCENTRATIONS

PARTICULATES

SUMMER

DATA VALUE EXTREMES ARE 71.09 369.15

units are in μg/m³



```
SY [illegible]
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
   ([illegible])

  71.09     87.5    105.0    122.5    140.0    157.5    175.0    192.5    ABOVE
  87.5     105.0    122.5    140.0    157.5    175.0    192.5    210.0    210.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

          12.5     12.5     12.5     12.5     12.5     12.5     12.5     12.5

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
LEVEL      1        2        3        4        5        6        7        8        9

SYMBOLS

FREQ.     [illegible] [illegible] 1   1   [illegible]   1   [illegible] [illegible]   1
```

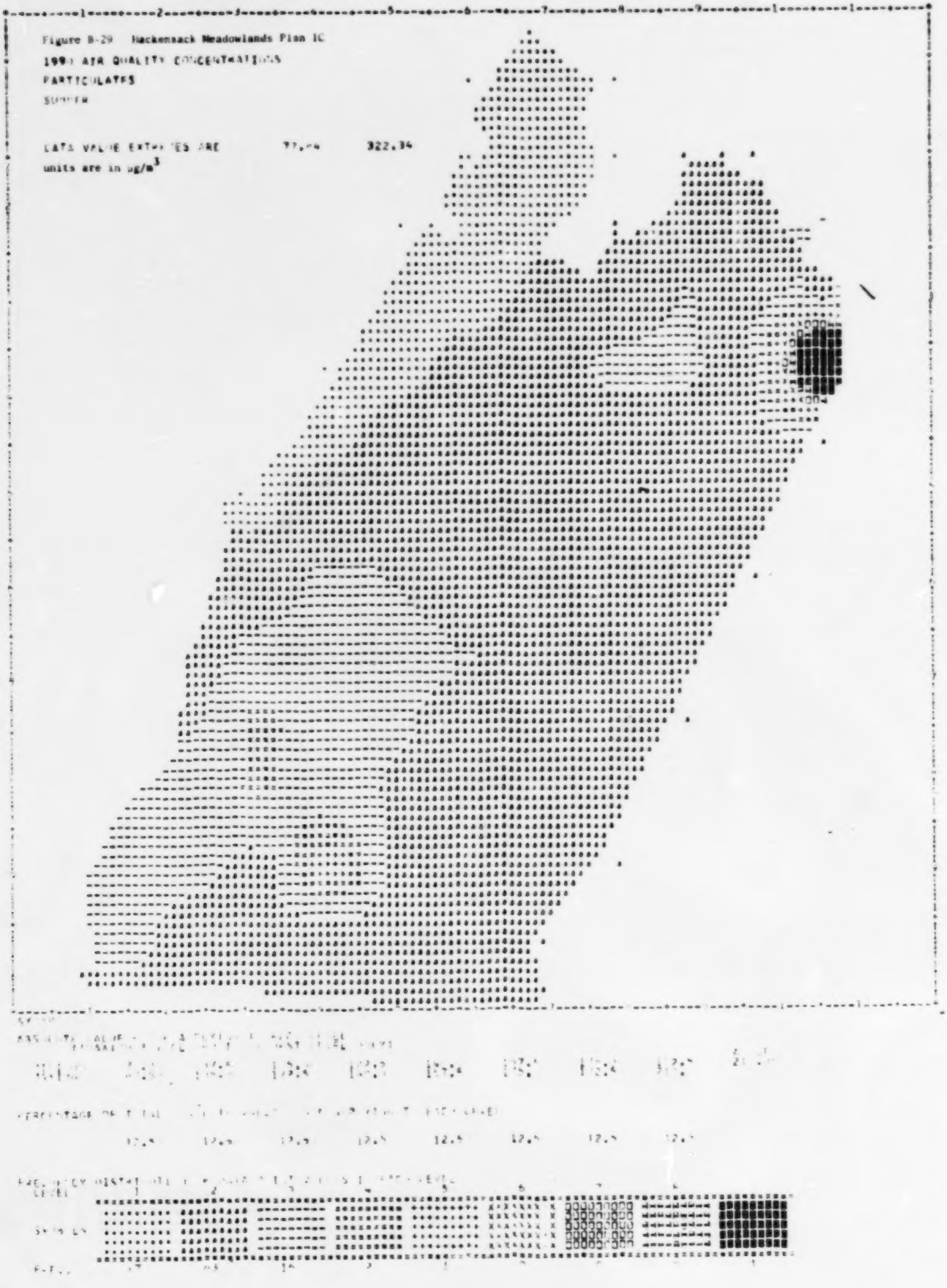


Figure B-29 Hackensack Meadowlands Plan IC

1990 AIR QUALITY CONCENTRATIONS

PARTICULATES

SUMMER

DATA VALUE EXTREMES ARE 77.04 322.34

units are in $\mu g/m^3$

SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
12.5
12.5
12.5
12.5
12.5
12.5
12.5
12.5
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
LEVEL
1
2
3
4
5
6
7
8
9
SYMBOLS
FREQ.
1

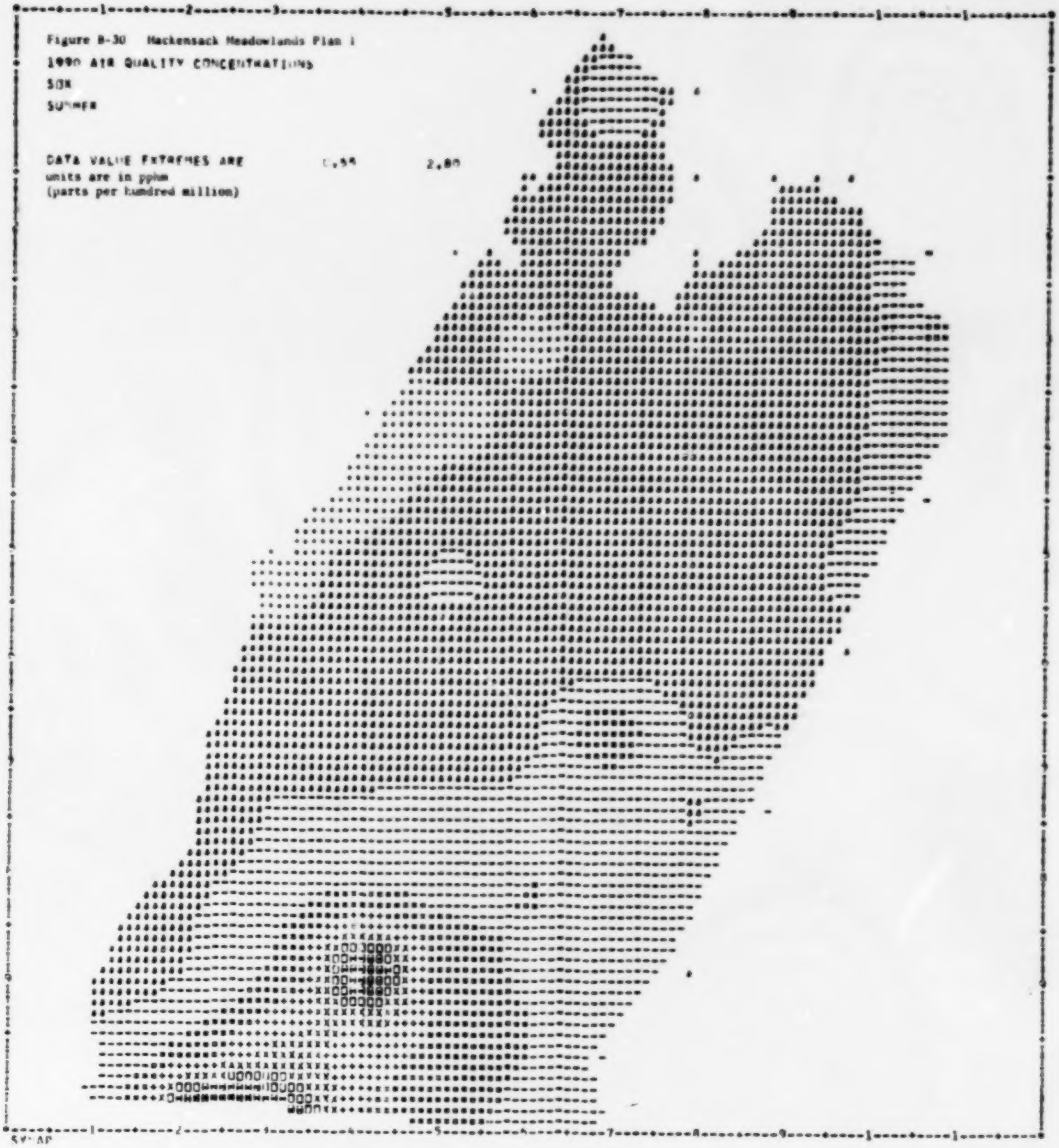


Figure B-30 Hackensack Meadowlands Plan I

1990 AIR QUALITY CONCENTRATIONS

SOX

SUMMER

DATA VALUE EXTREMES ARE 0.55 2.80

units are in pphm
(parts per hundred million)

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
        ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM     0.40    0.60    0.80    1.00    1.20    1.40    1.60    1.80    2.00    2.20    ABOVE
 MAXIMUM     0.60    0.80    1.00    1.20    1.40    1.60    1.80    2.00    2.20    2.40     2.40

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

            10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL        1       2       3       4       5       6       7       8       9      10       H

 FREQ.        6      51      28      13       1       1       0       1       1       0       1
```

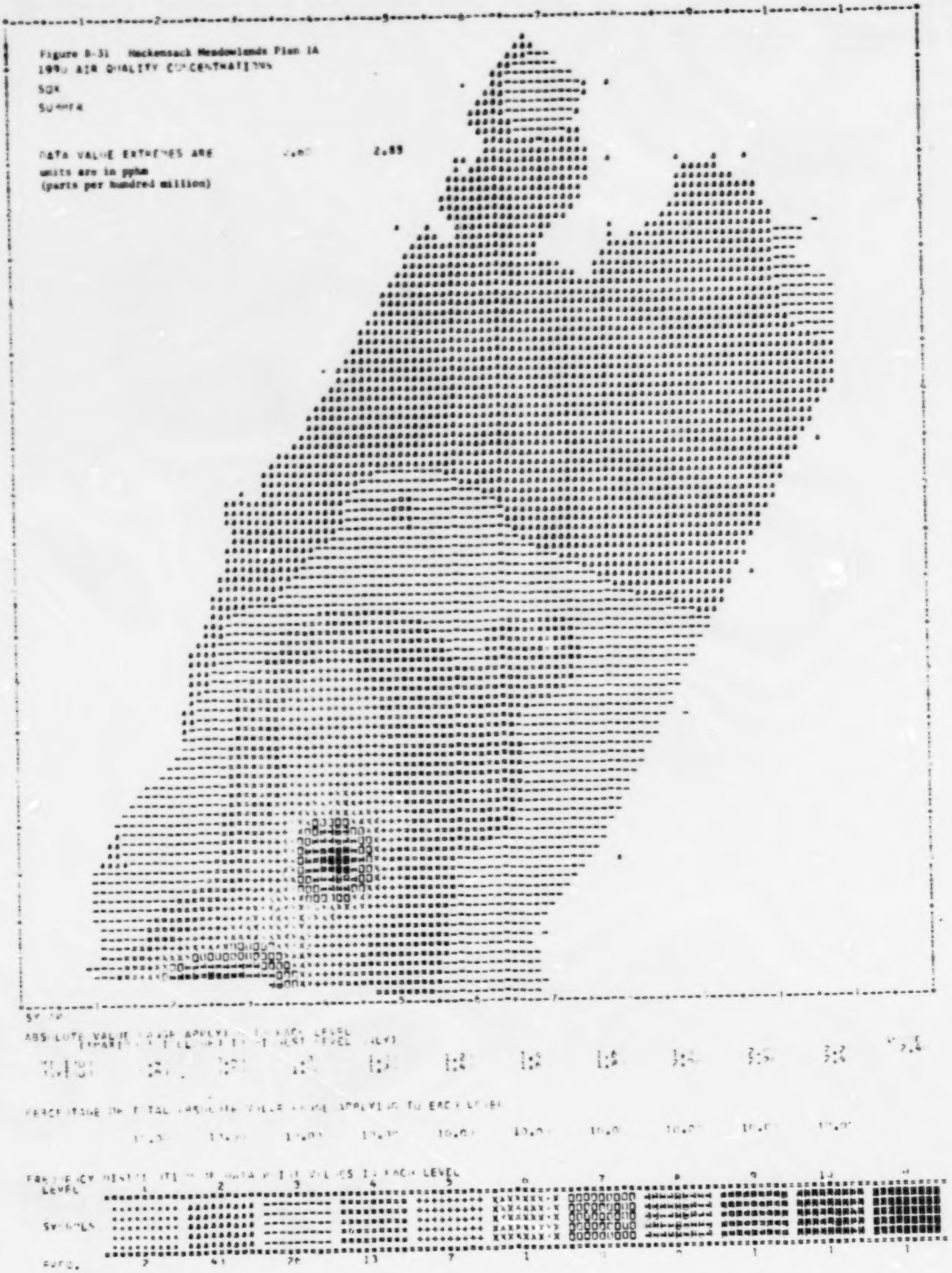


Figure 8-31 Hackensack Meadowlands Plan 1A

1990 AIR QUALITY CONCENTRATIONS

SOX

SUMMER

DATA VALUE EXTREMES ARE [illegible] 2.85

units are in pphm
(parts per hundred million)

SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)
MINIMUM
MAXIMUM
PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
LEVEL
SYMBOLS
FREQ.

LEVEL	1	2	3	4	5	6	7	8	9	10	11
FREQ.	2	41	26	13	7	1	0	0	1	1	1

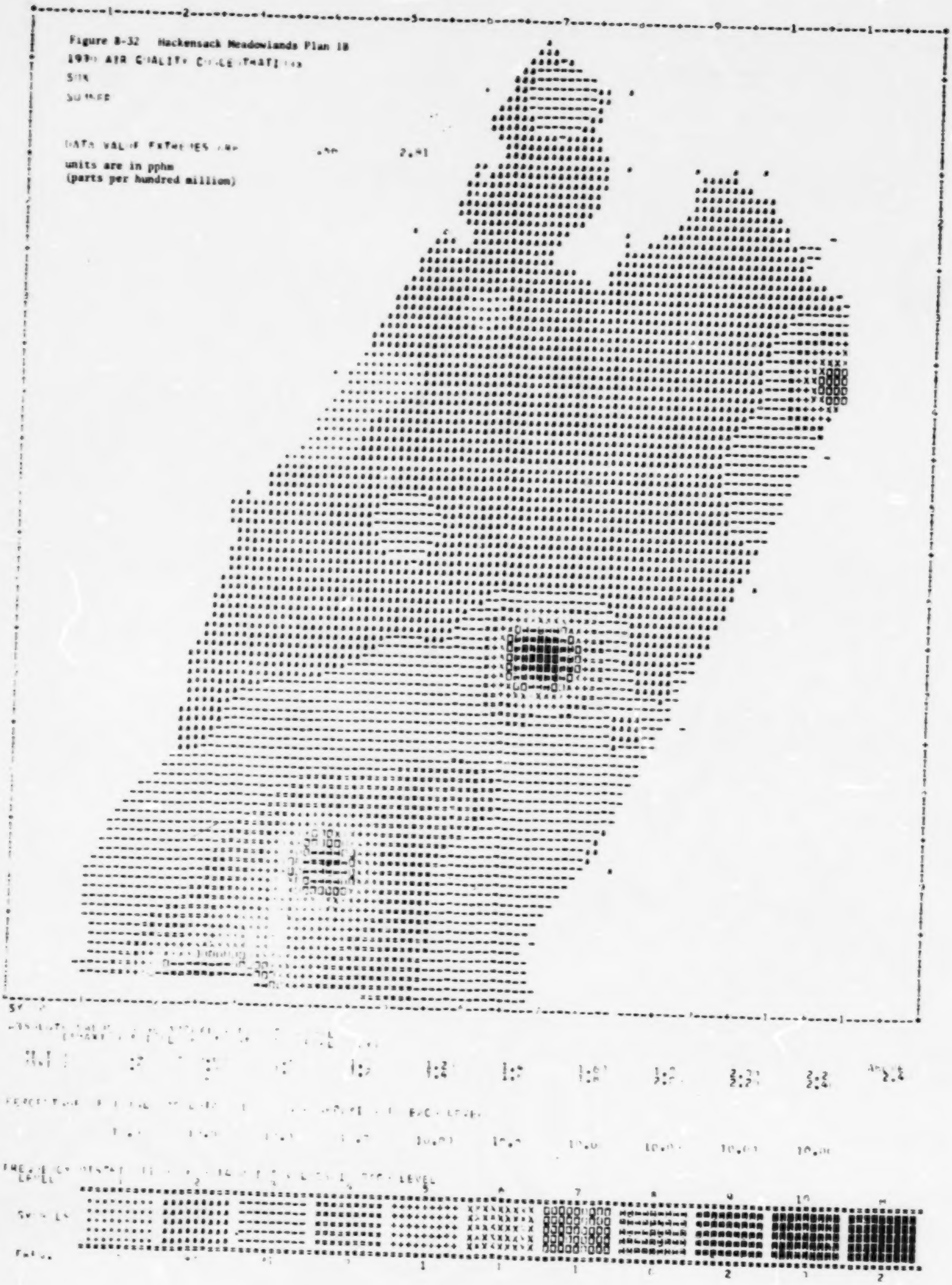
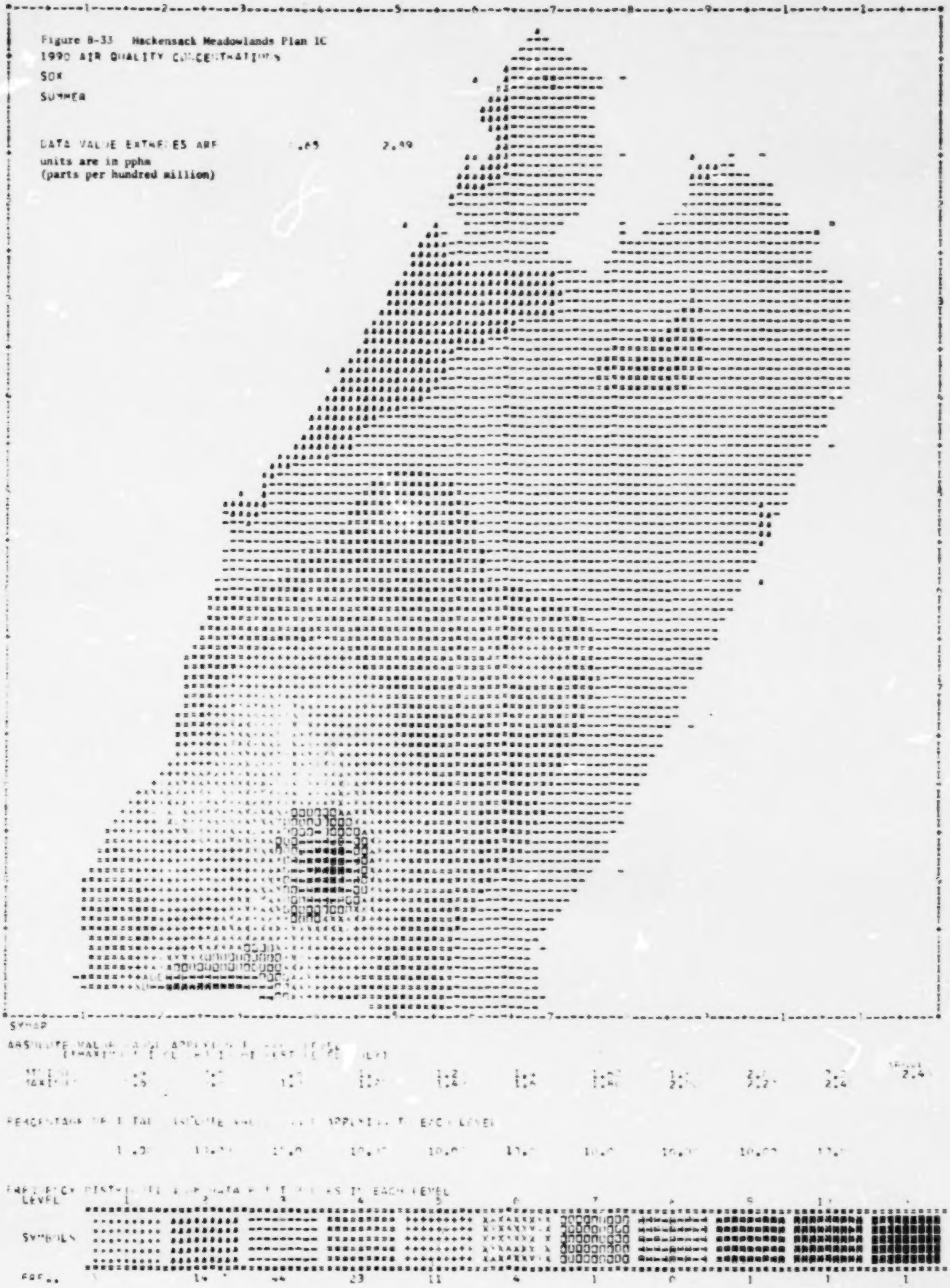


Figure 8-32 Hackensack Meadowlands Plan 1B

199[illegible] AIR QUALITY C[illegible]

units are in pphm
(parts per hundred million)

LEVEL
1
2
3
4
5
6
7
8
9
10
SYMBOLS
238



SYMAP
SYMBOLS
LEVEL
1
2
3
4
5
6
7
9
FREQ.
14
23
11
1
0
1
1
1

Figure 8-33 Hackensack Meadowlands Plan 1C
1990 AIR QUALITY CONCENTRATIONS
SOX
SUMMER

DATA VALUE EXTREMES ARE .65 2.49
units are in pphm
(parts per hundred million)

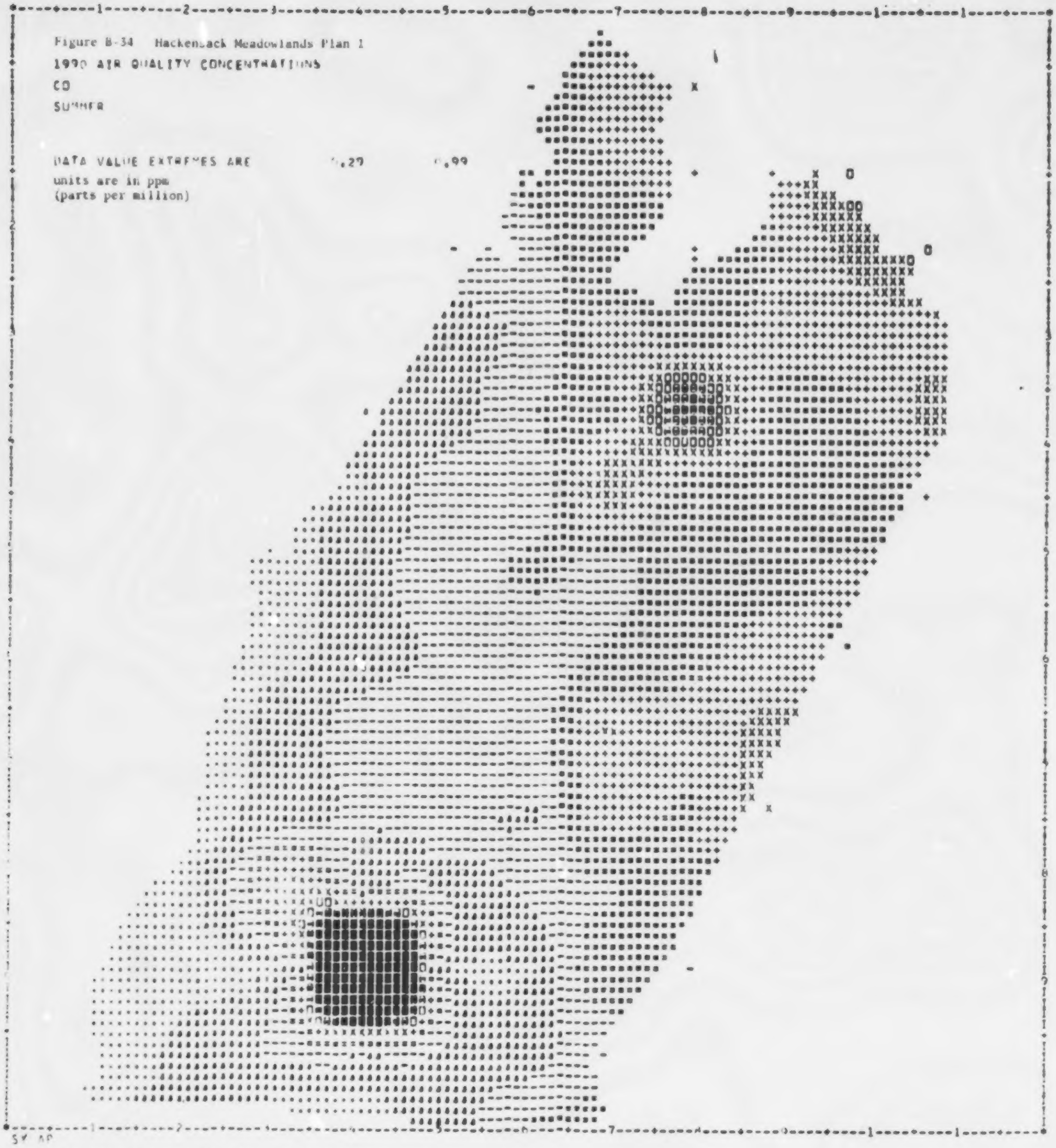


Figure B-34 Hackensack Meadowlands Plan 1
1990 AIR QUALITY CONCENTRATIONS
CO
SUMMER

DATA VALUE EXTREMES ARE 0.27 0.99
units are in ppm
(parts per million)

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM   BELOW    0.30    0.32    0.34    0.36    0.38    0.40    0.42    0.44    0.46    0.48    ABOVE
 MAXIMUM    0.30    0.32    0.34    0.36    0.38    0.40    0.42    0.44    0.46    0.48    0.50     0.50

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

                   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00   10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL       1       1       2       3       4       5       6       7       8       9      10       +

 SYMBOLS

 FREQ.       1      11      14      23      22      14       4       3       0       1       0       1
```

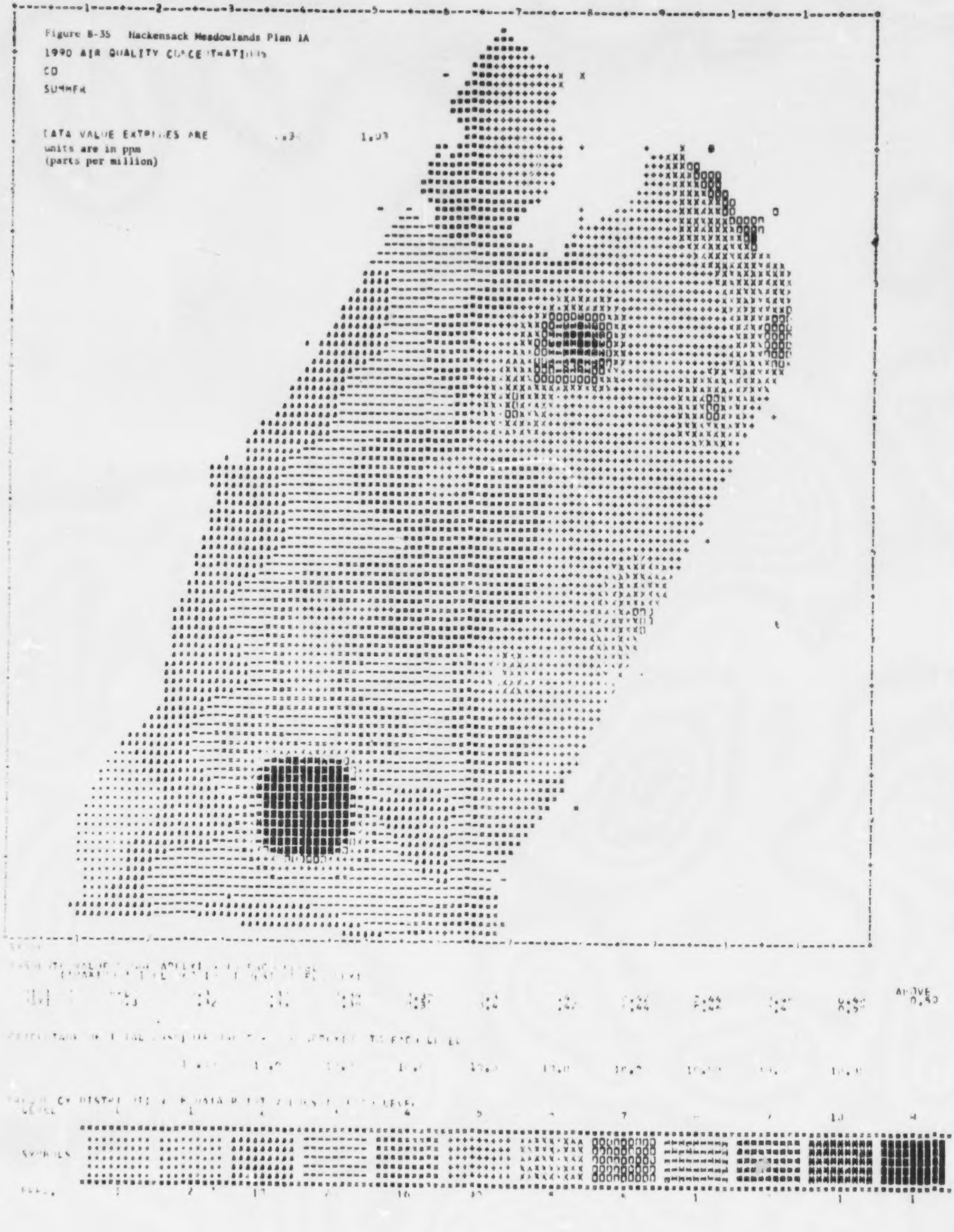


Figure B-35 Hackensack Meadowlands Plan 1A

1990 AIR QUALITY CONCENTRATIONS

CO

SUMMER

DATA VALUE EXTREMES ARE .3 1.03

units are in ppm
(parts per million)

ABOVE
LEVEL
SYMBOLS

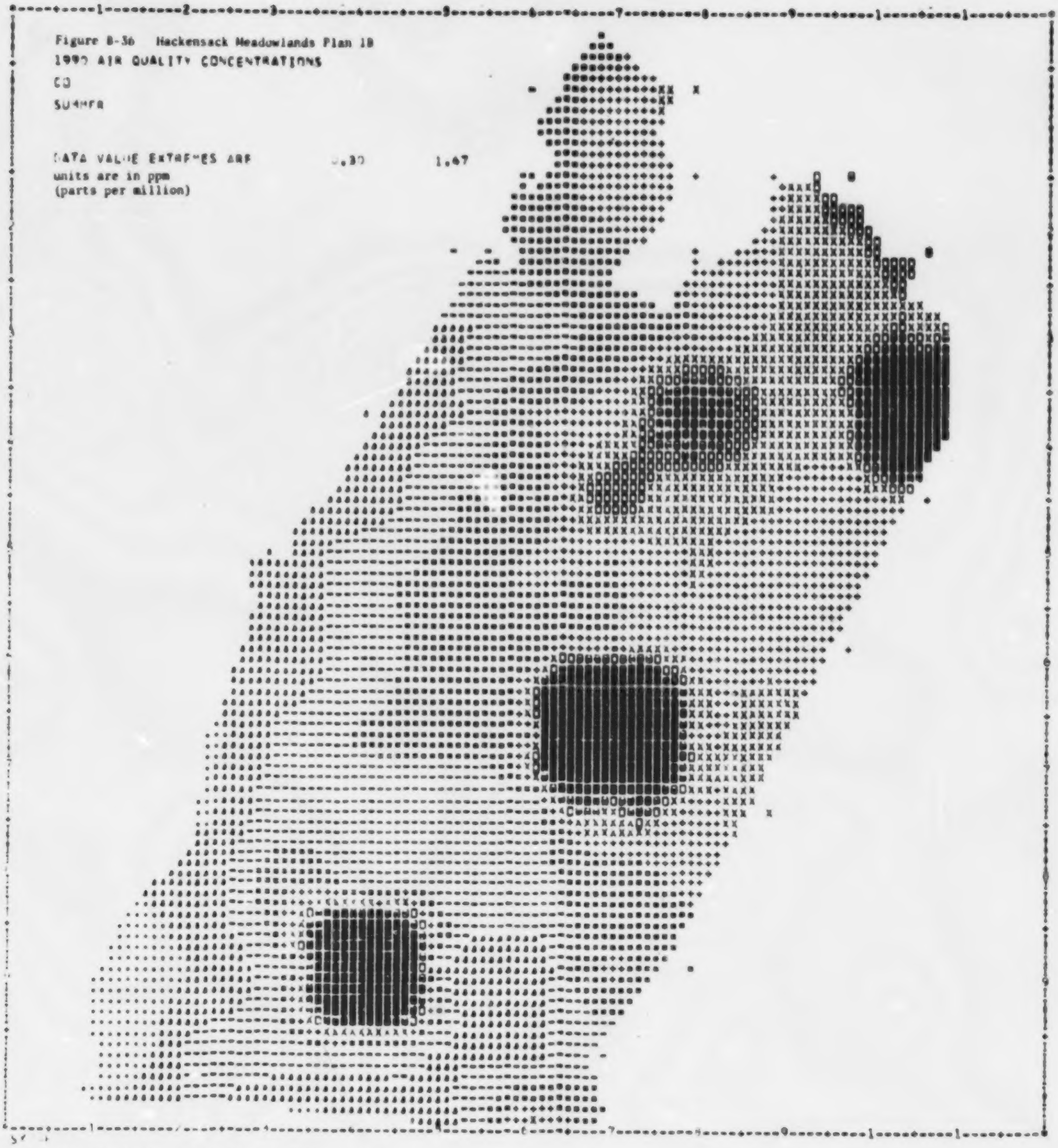


Figure 8-36 Hackensack Meadowlands Plan 1B
1990 AIR QUALITY CONCENTRATIONS
CO
SUMMER

DATA VALUE EXTREMES ARE 0.30 1.47
units are in ppm
(parts per million)

```
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM    BELOW   0.30   0.32   0.34   0.36   0.38   0.40   0.42   0.44   0.46   0.48   ABOVE
 MAXIMUM     0.30   0.32   0.34   0.36   0.38   0.40   0.42   0.44   0.46   0.48   0.50    0.50

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

                   10.00  10.00  10.00  10.00  10.00  10.00  10.00  10.00  10.00  10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL         L      1      2      3      4      5      6      7      8      9     10      H

 SYMBOLS

 FREQ.         1      5     14     21     17     21     16      1      2      0      1      3
```

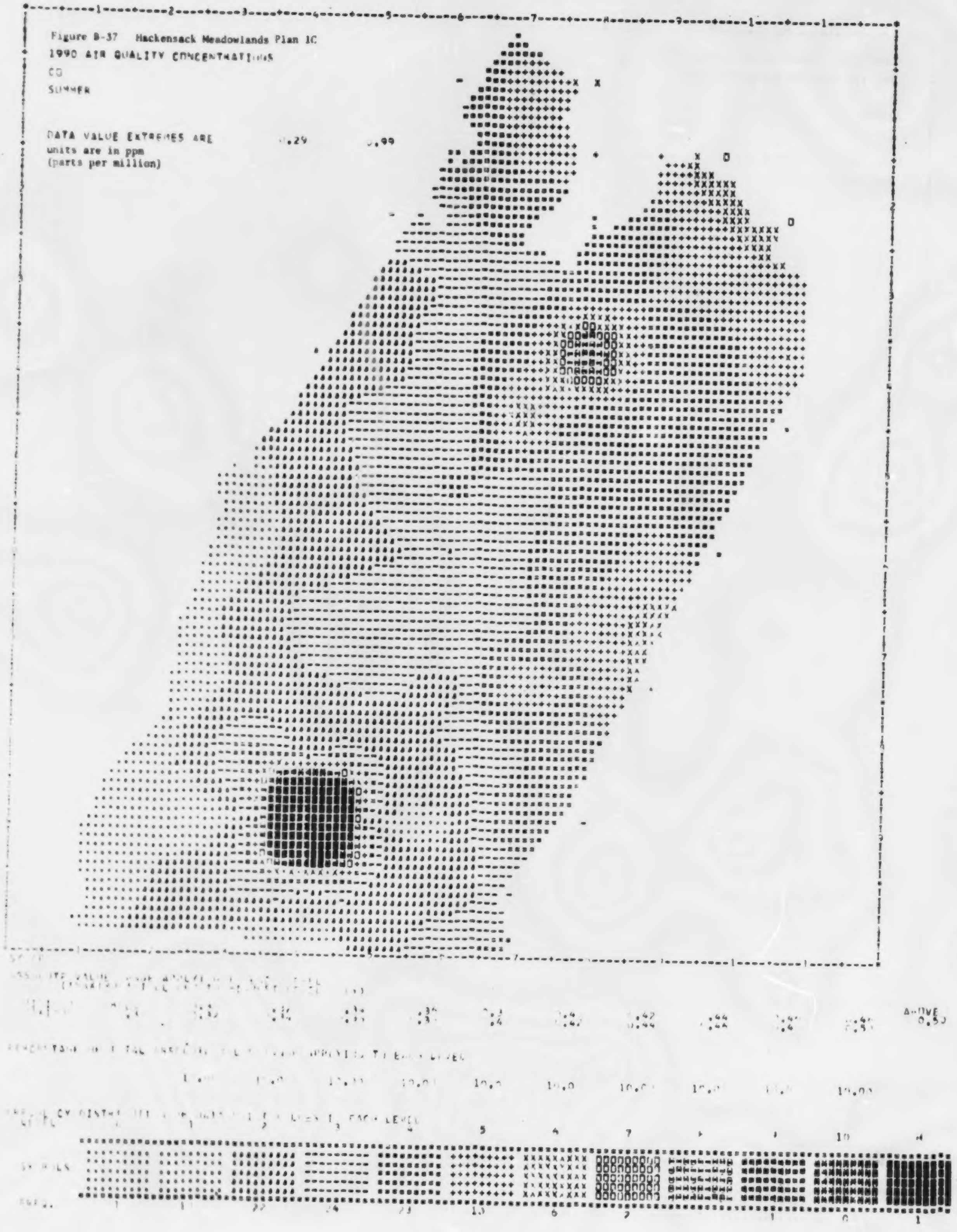


Figure B-37 Hackensack Meadowlands Plan 1C
1990 AIR QUALITY CONCENTRATIONS
CO
SUMMER

DATA VALUE EXTREMES ARE 0.29 0.99
units are in ppm
(parts per million)

0.42
0.44
ABOVE
0.50
5
6
7
10
1
13
6
2
1
0
1

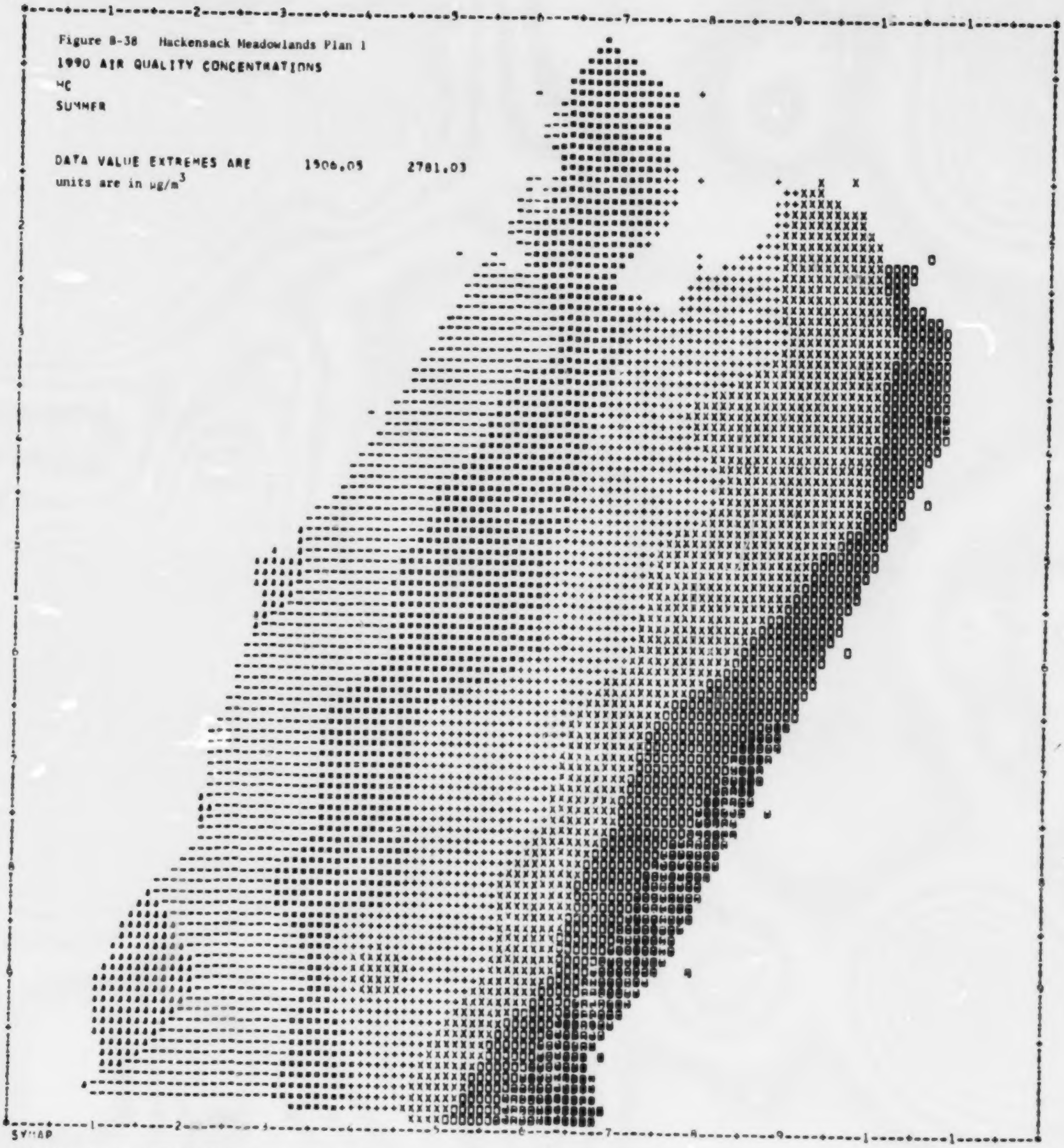


Figure 8-38 Hackensack Meadowlands Plan 1

1990 AIR QUALITY CONCENTRATIONS

HC

SUMMER

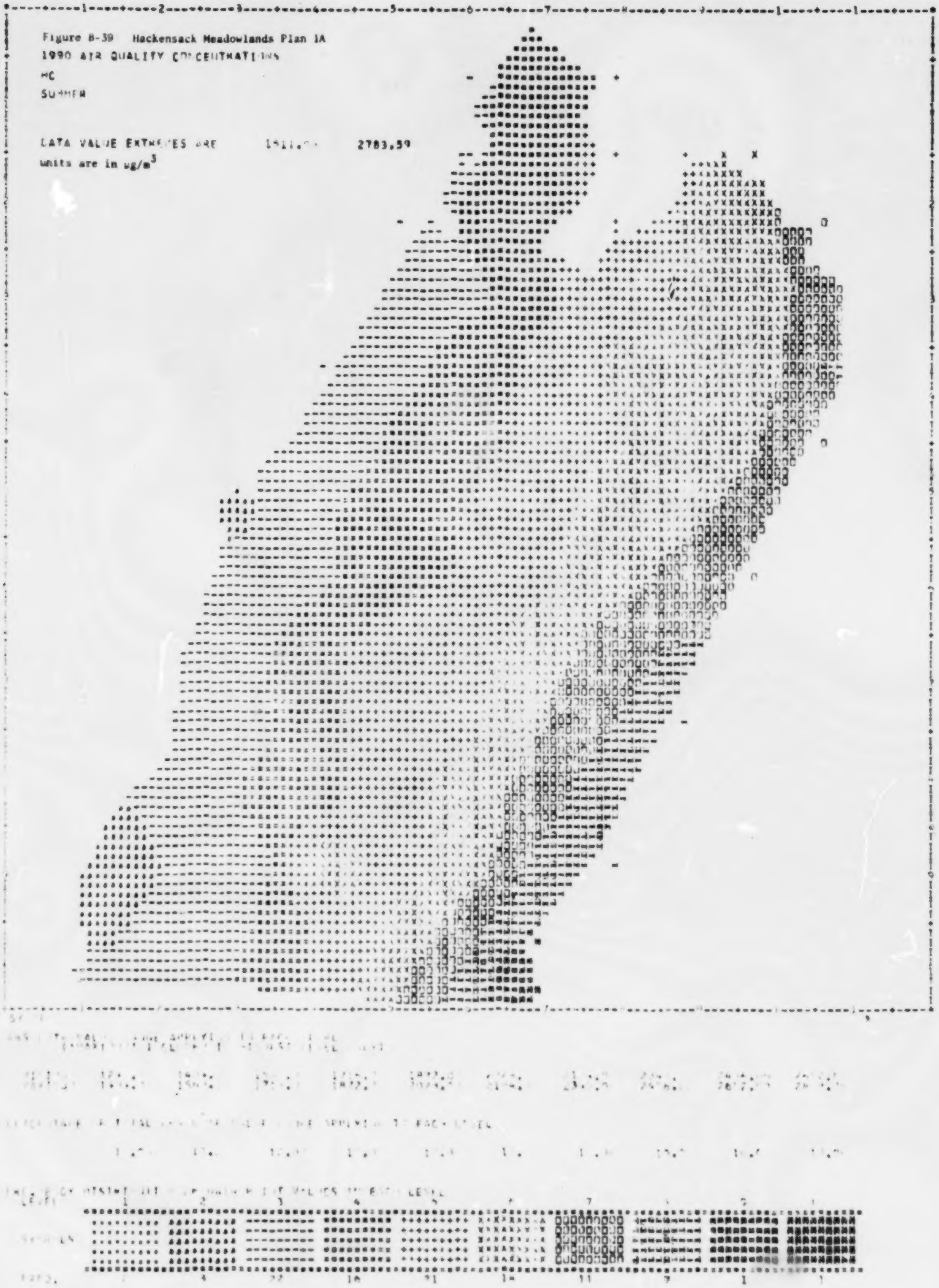
DATA VALUE EXTREMES ARE 1506.05 2781.03

units are in $\mu g/m^3$

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM   1248.00   1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00
 MAXIMUM   1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00   2808.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

           10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL         1         2         3         4         5         6         7         8         9        10
 SYMBOLS   .........  &&&&&&&&&  ---------  ■■■■■■■■■  +++++++++  XXXXXXXXX  OOOOOOOOO  ▨▨▨▨▨▨▨▨▨  █████████  █████████
 FREQ.         0         4        22        17        20        17        11         7         1         1
```

Figure 8-39 Hackensack Meadowlands Plan 1A
1990 AIR QUALITY CONCENTRATIONS
HC
SUMMER

DATA VALUE EXTREMES ARE 1511.[illegible] 2783.59
units are in $\mu g/m^3$



LEVEL 1 2 3 4 5 6 7 8 9 10
FREQ. 4 22 16 21 14 11 7 1 1

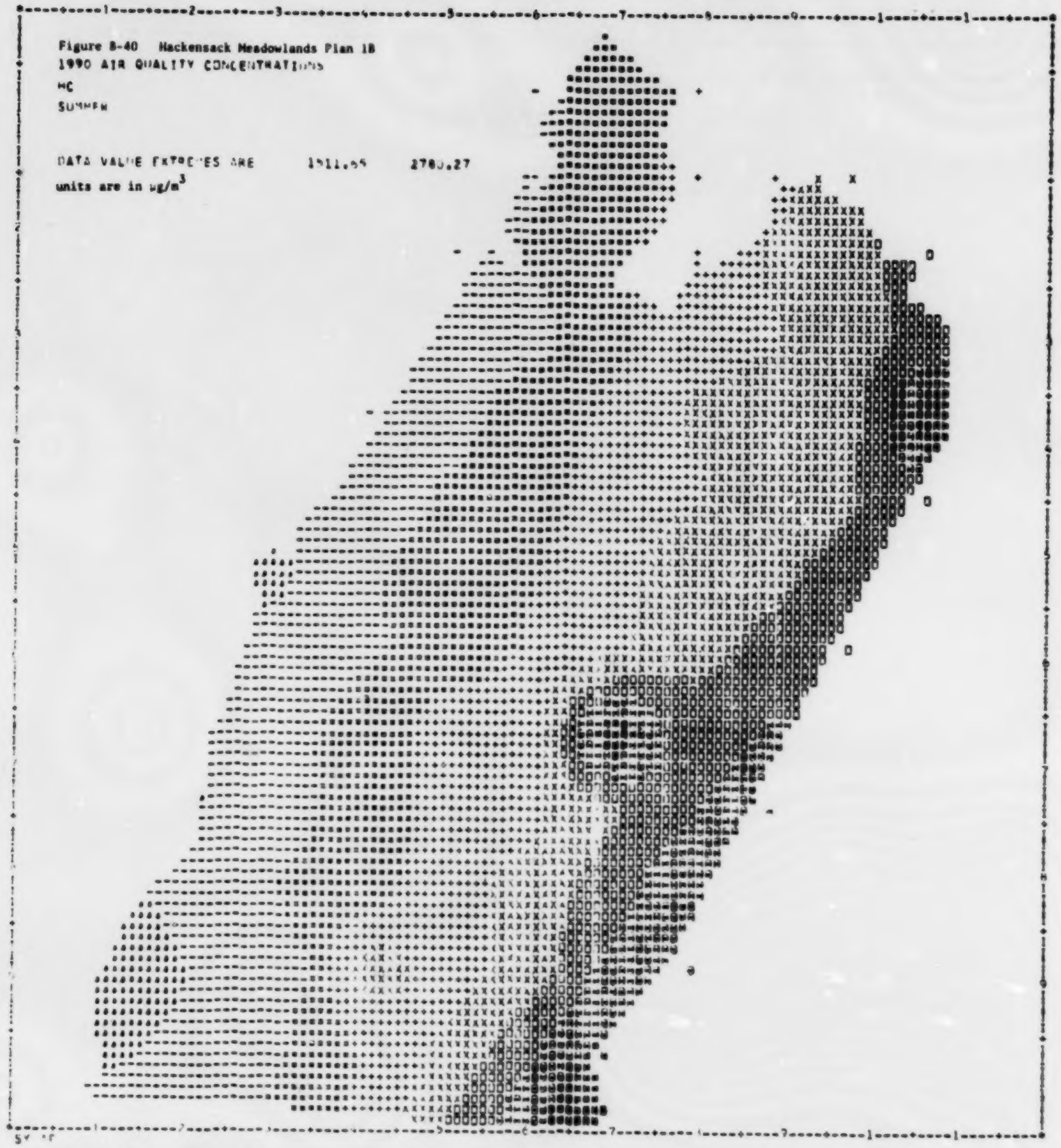


Figure 8-40 Hackensack Meadowlands Plan 1B
1990 AIR QUALITY CONCENTRATIONS
HC
SUMMER

DATA VALUE EXTREMES ARE 1511.55 2780.27
units are in $\mu g/m^3$

```
SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM  1247.[illegible]  1404.[illegible]  1560.[illegible]  1715.[illegible]  1872.0[illegible]  2028.[illegible]  2136.00  2340.00  2496.00  2652.00
 MAXIMUM  1404.[illegible]  1560.00  1716.0[illegible]  1872.[illegible]  2028.[illegible]  2136.[illegible]  2340.00  2496.00  2652.00  2808.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

          1[illegible]    1[illegible]    1[illegible]    10.[illegible]    10.0[illegible]    10.[illegible]    10.00    10.[illegible]    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL        1         2         3         4         5         6         7         8         9        10

 SYMBOLS

 FREQ.                  3        22        17        20        17        11         6         3         1
```

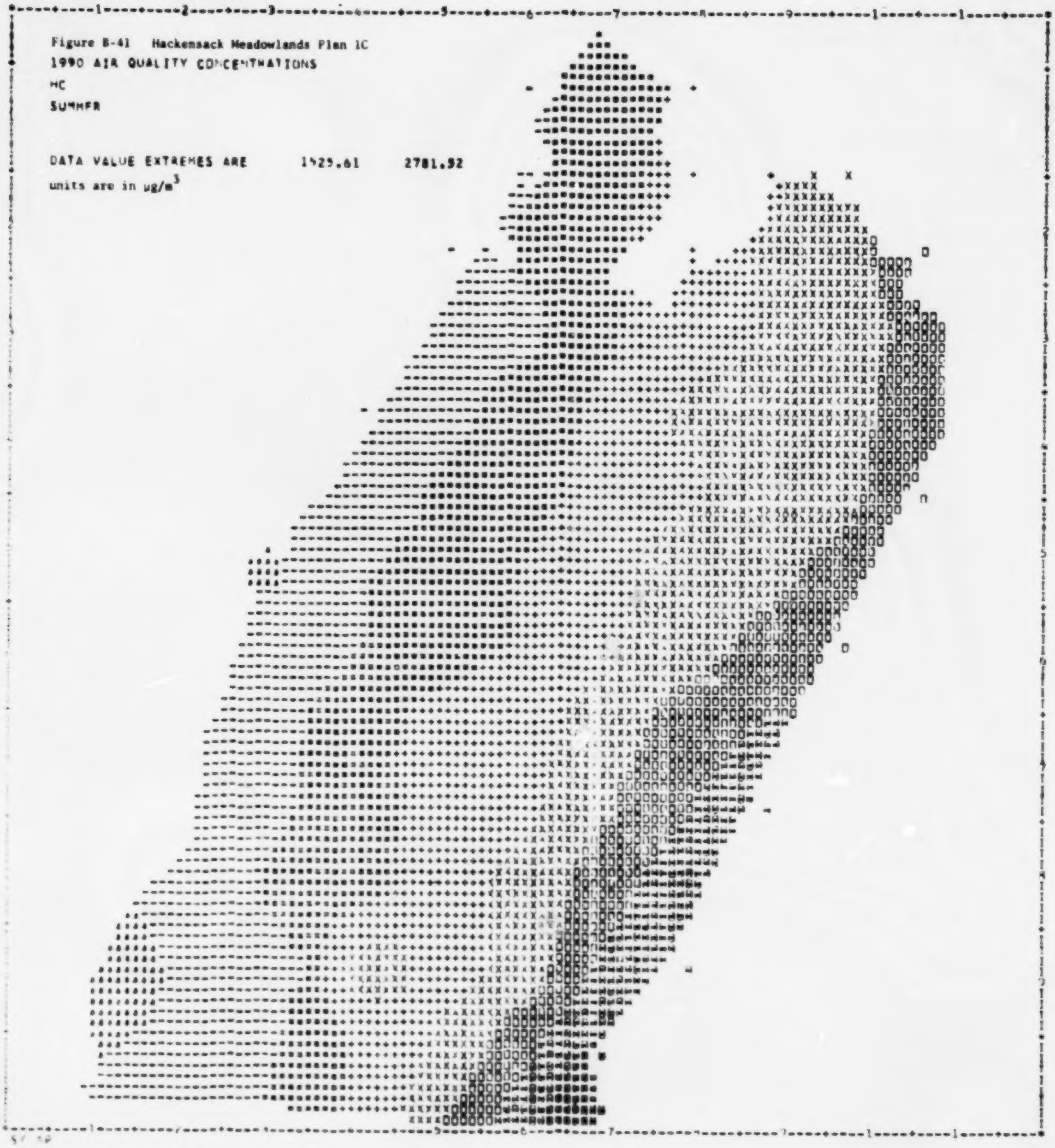


Figure B-41 Hackensack Meadowlands Plan 1C
1990 AIR QUALITY CONCENTRATIONS
HC
SUMMER

DATA VALUE EXTREMES ARE 1429.61 2781.92
units are in $\mu g/m^3$

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

 [illegible]  1248.00   1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00
 [illegible]  1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00   2808.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL          1         2         3         4         5         6         7         8         9        10

 SYMBOLS

 FREQ.                    1        23        17        22        19        12         6         1         1
```

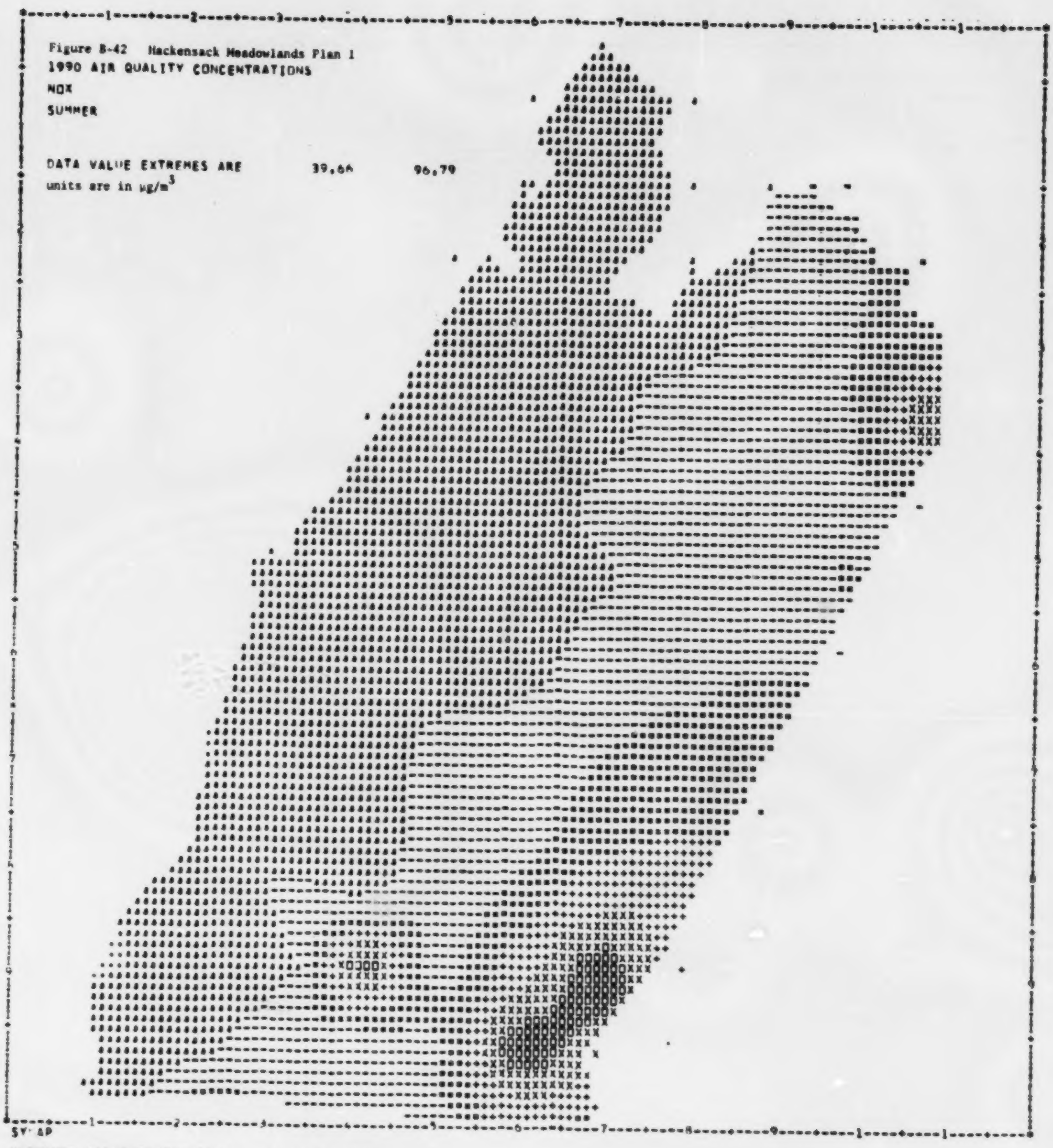


Figure 8-42 Hackensack Meadowlands Plan 1
1990 AIR QUALITY CONCENTRATIONS
NOX
SUMMER

DATA VALUE EXTREMES ARE 39.66 96.79
units are in $\mu g/m^3$

```
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM     30.00    40.00    50.00    60.00    70.00    80.00    90.00   100.00   110.00   120.00
  MAXIMUM     40.00    50.00    60.00    70.00    80.00    90.00   100.00   110.00   120.00   130.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1        2        3        4        5        6        7        8        9       10

  SYMBOLS        .        #        -        ●        +        X        O        ▨        ▩        █

  FREQ.          1       45       33       10        6        2        3        0        0        0
```

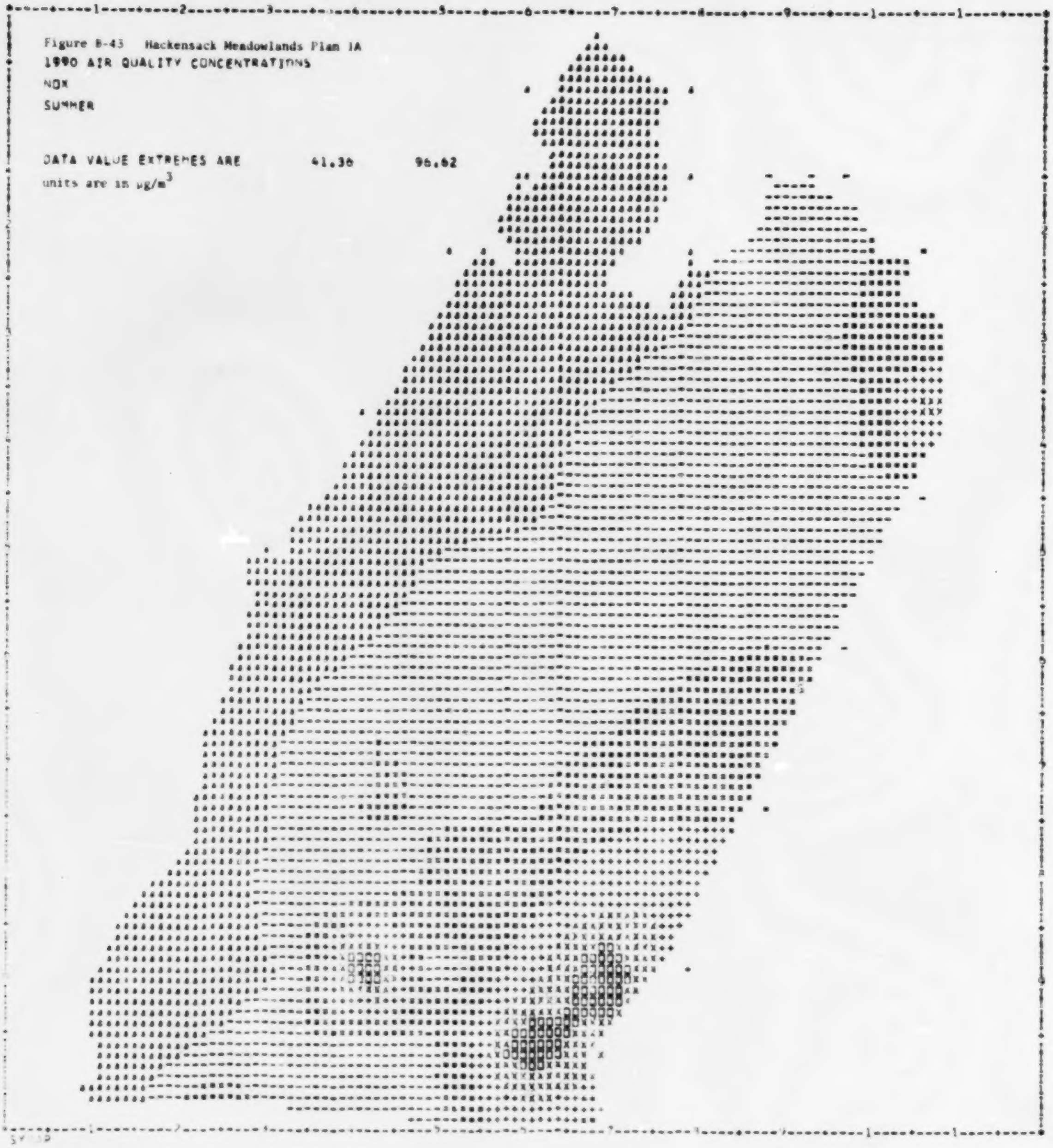


Figure B-43 Hackensack Meadowlands Plan 1A
1990 AIR QUALITY CONCENTRATIONS
NOX
SUMMER

DATA VALUE EXTREMES ARE 41.36 96.62
units are in $\mu g/m^3$

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM     30.00    40.00    50.00    60.00    70.00    80.0     90.00    100.00   110.00   120.00
 MAXIMUM     40.00    50.00    60.0     70.00    80.00    90.0    100.00    110.00   120.00   130.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00    10.00    10.00    10.00    10.00    10.0     10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL        1        2        3        4        5        6        7        8        9        10

  SYMBOLS

  FREQ.    [illegible]  41       44       14       6        2        3        0        0        0
```

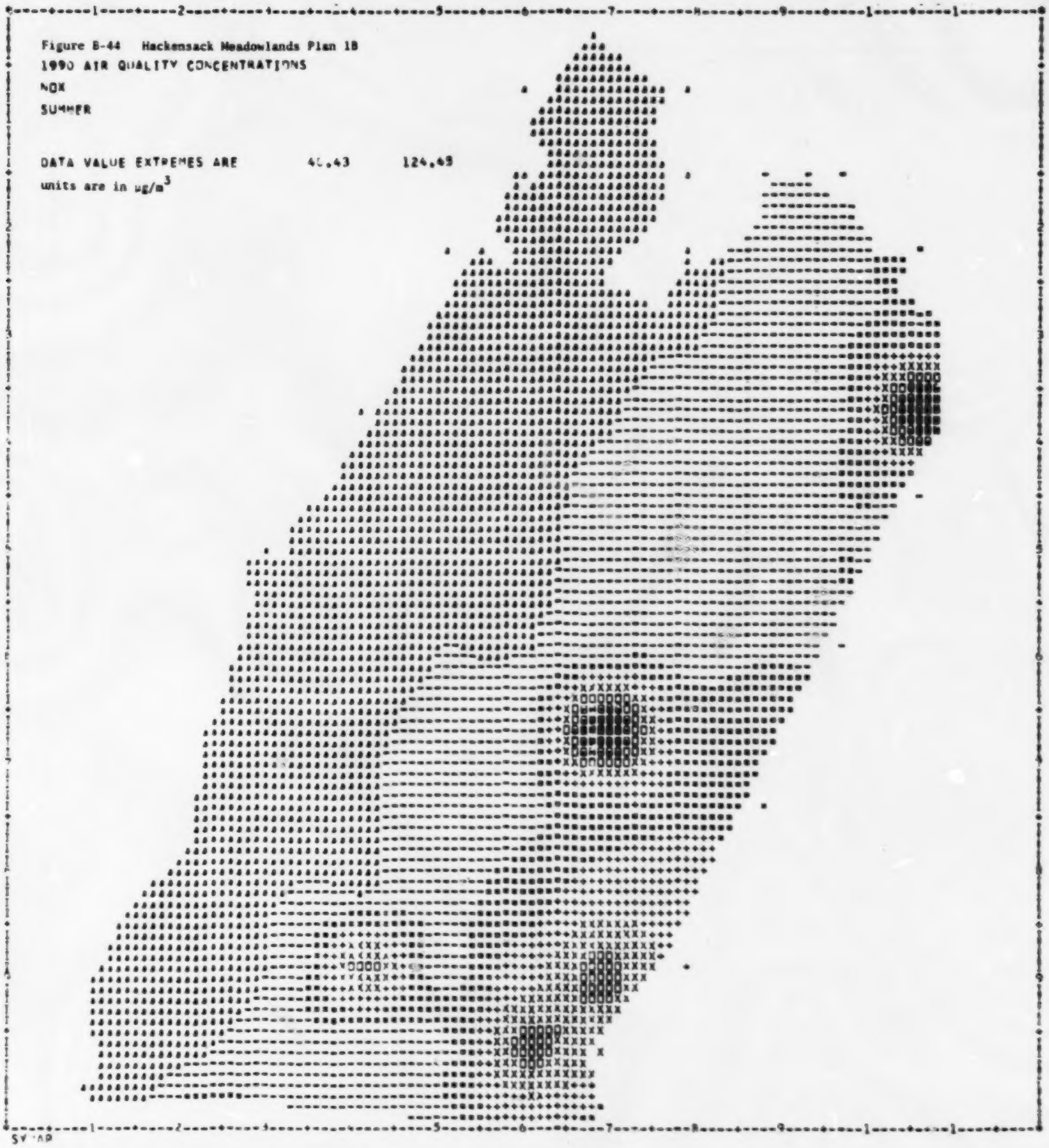


Figure B-44 Hackensack Meadowlands Plan 1B
1990 AIR QUALITY CONCENTRATIONS
NOX
SUMMER

DATA VALUE EXTREMES ARE 40.43 124.49
units are in μg/m³

```
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM     30.00    40.00    50.00    60.00    70.00    80.00    90.00   100.00   110.00   120.00
 MAXIMUM     40.00    50.00    60.00    70.00    80.00    90.00   100.00   110.00   120.00   130.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
   LEVEL       1        2        3        4        5        6        7        8        9        10

  SYMBOLS

   FREQ.       0       43       34       11        6        1        3        0        0        2
```

Figure 8-45 Hackensack Meadowlands Plan 1C

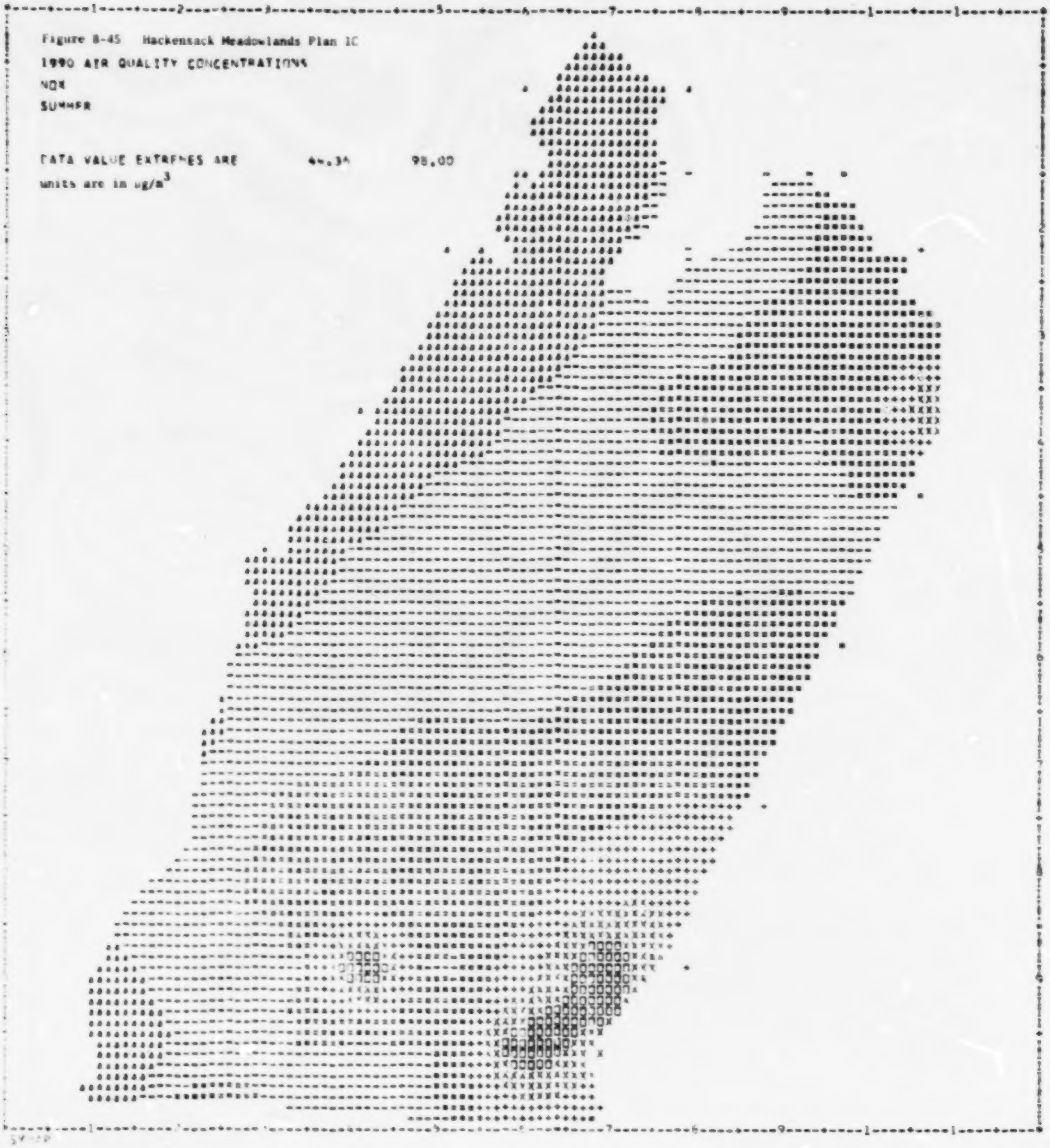
1990 AIR QUALITY CONCENTRATIONS

NOX

SUMMER

DATA VALUE EXTREMES ARE 44.34 98.00

units are in $\mu g/m^3$

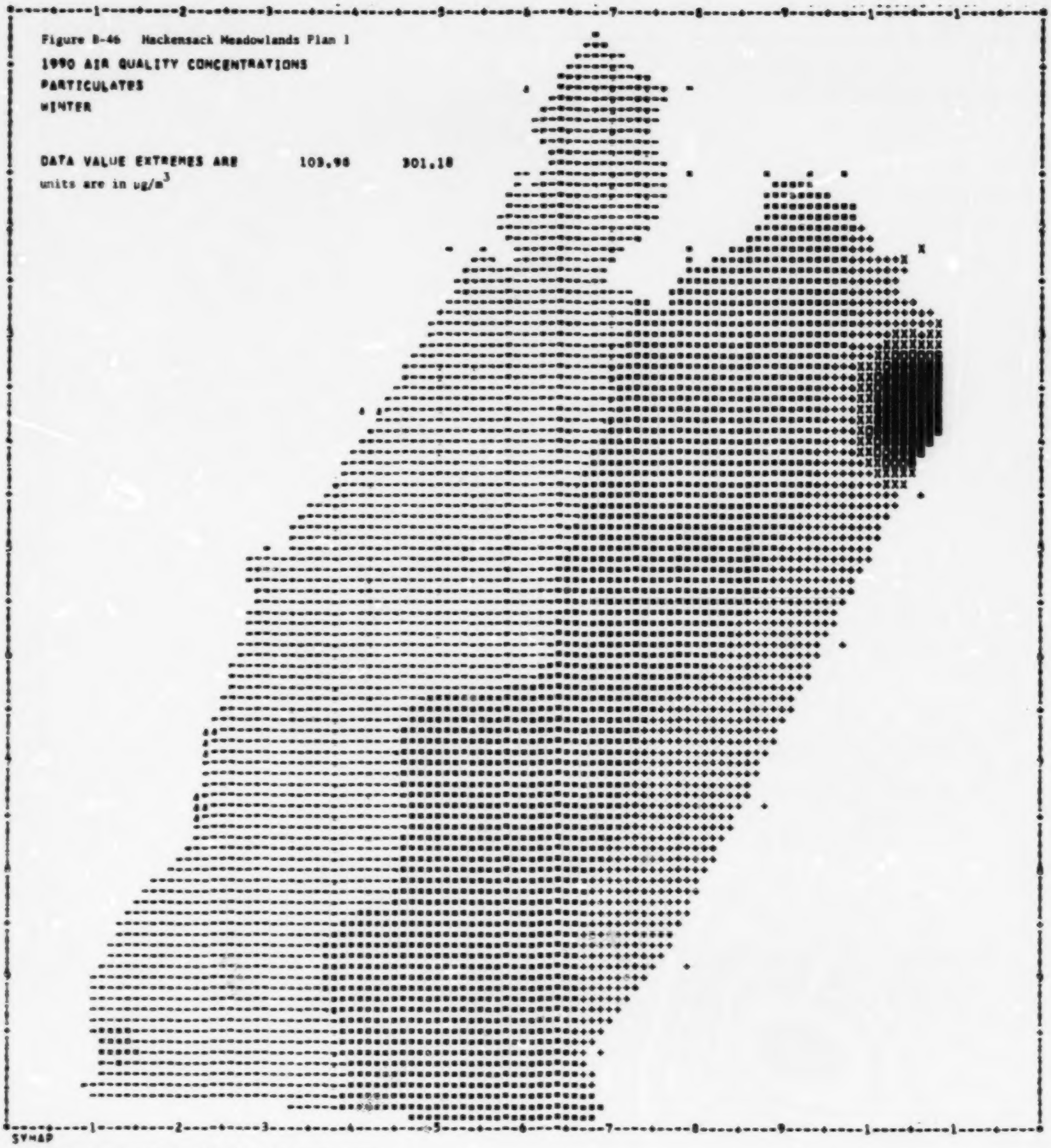


```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM     30.00     40.00     50.00     60.00     70.00     80.00     90.00    100.00    110.00    120.00
 MAXIMUM     40.00     50.00     60.00     70.00     80.00     90.00    100.00    110.00    120.00    130.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL        1         2         3         4         5         6         7         8         9        10

 FREQ.         1        19        39        28         9         7         3         0         0         0
```

Figure B-46 Hackensack Meadowlands Plan 1

1990 AIR QUALITY CONCENTRATIONS
PARTICULATES
WINTER

DATA VALUE EXTREMES ARE 103.98 301.18
units are in $\mu g/m^3$



```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
       ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM     70.00     87.50    105.00    122.50    140.00    157.50    175.00    192.50     ABOVE
 MAXIMUM     87.50    105.00    122.50    140.00    157.50    175.00    192.50    210.00    210.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             12.50     12.50     12.50     12.50     12.50     12.50     12.50     12.50

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL         1         2         3         4         5         6         7         8         H

 SYMBOLS   .........  '''''''''  ---------  =========  +++++++++  XXXXXXXXX  OOOOOOOOO  @@@@@@@@@  █████████

 FREQ.         0         4        40        38        16         1         0         0         1
```

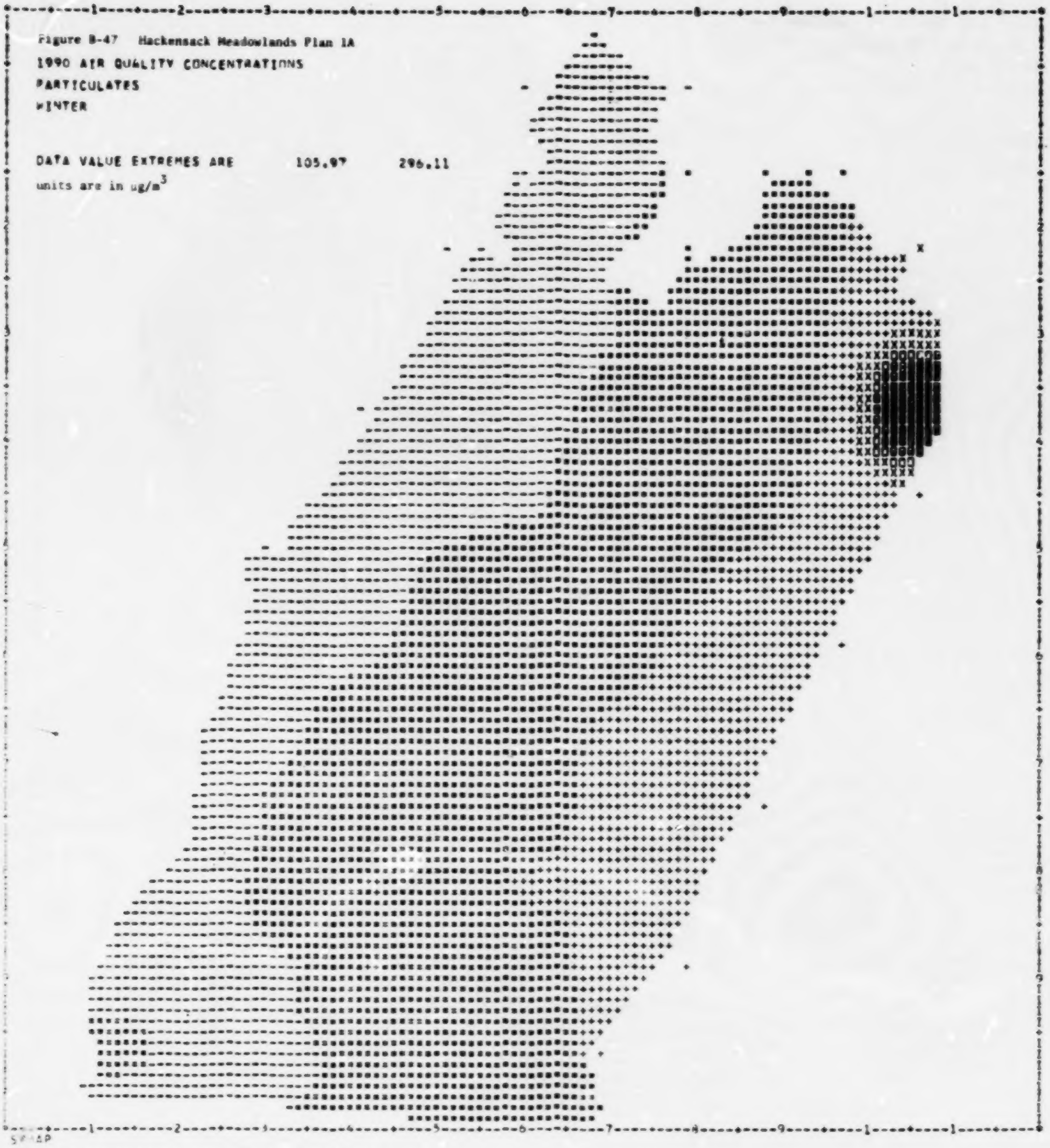


Figure B-47 Hackensack Meadowlands Plan 1A

1990 AIR QUALITY CONCENTRATIONS

PARTICULATES

WINTER

DATA VALUE EXTREMES ARE 105.97 296.11

units are in $\mu g/m^3$

```
SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

                                                                                              ABOVE
 MINIMUM      70.00     87.50    105.00    122.50    140.00    157.50    175.00    192.50    210.00
 MAXIMUM      87.50    105.00    122.50    140.00    157.50    175.00    192.50    210.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              12.50     12.50     12.50     12.50     12.50     12.50     12.50     12.50

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL          1         2         3         4         5         6         7         8         H
 SYMBOLS    .........  #########  ---------  ========= +++++++++ XXXXXXXXX 000000000 @@@@@@@@@ █████████
 FREQ.          0         0        33        43        21         2         0         0   [illegible]
```

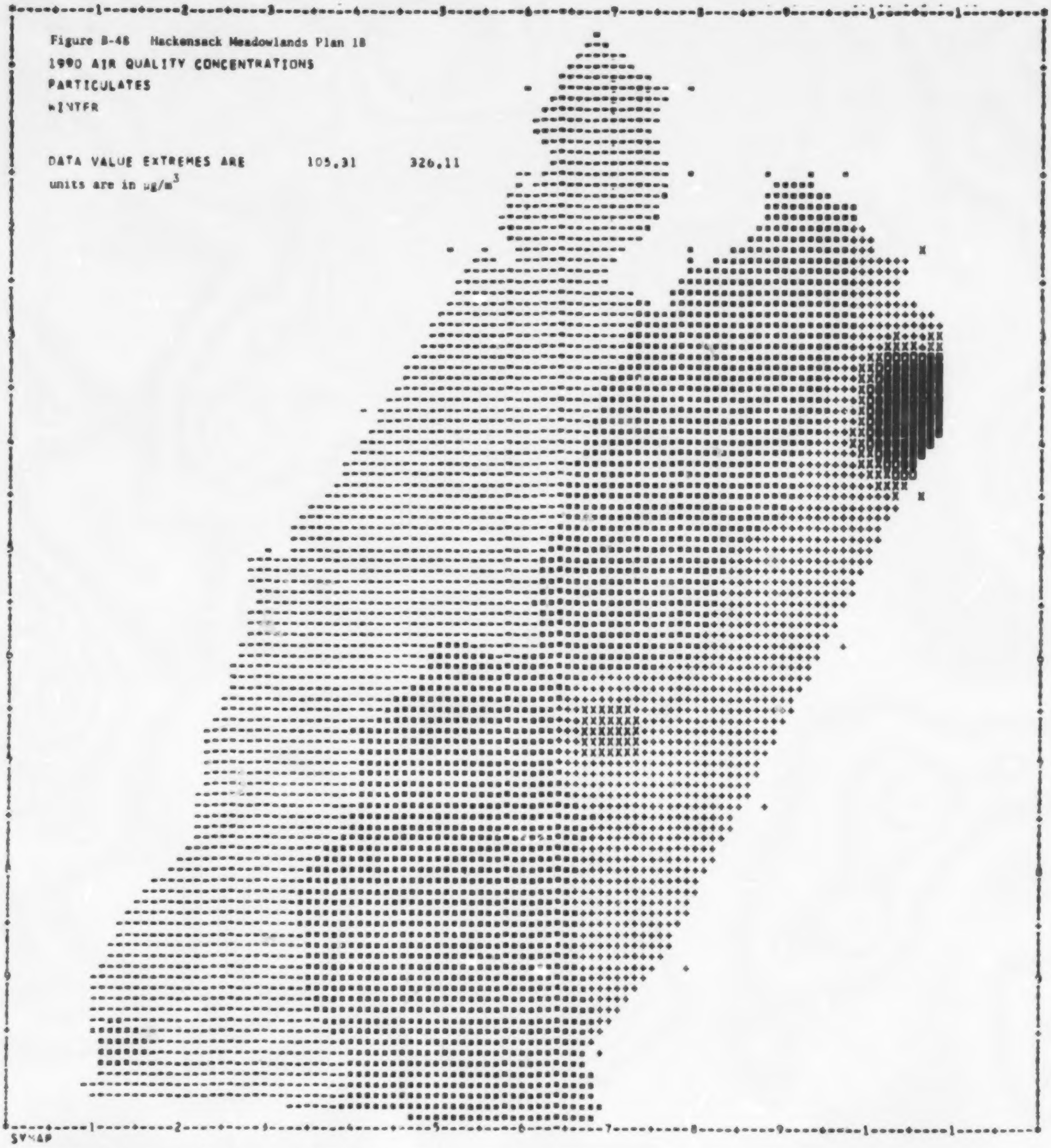


Figure B-48 Hackensack Meadowlands Plan 1B

1990 AIR QUALITY CONCENTRATIONS

PARTICULATES

WINTER

DATA VALUE EXTREMES ARE 105.31 326.11

units are in $\mu g/m^3$

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (*MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM      70.00     87.50    105.00    122.50    140.00    157.50    175.00    192.50     ABOVE
  MAXIMUM      87.50    105.00    122.50    140.00    157.50    175.00    192.50    210.00    210.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

               12.50     12.50     12.50     12.50     12.50     12.50     12.50     12.50

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL          1         2         3         4         5         6         7         8         H

  SYMBOLS

  FREQ.          5         0        39        40        17         3         0         0         1
```

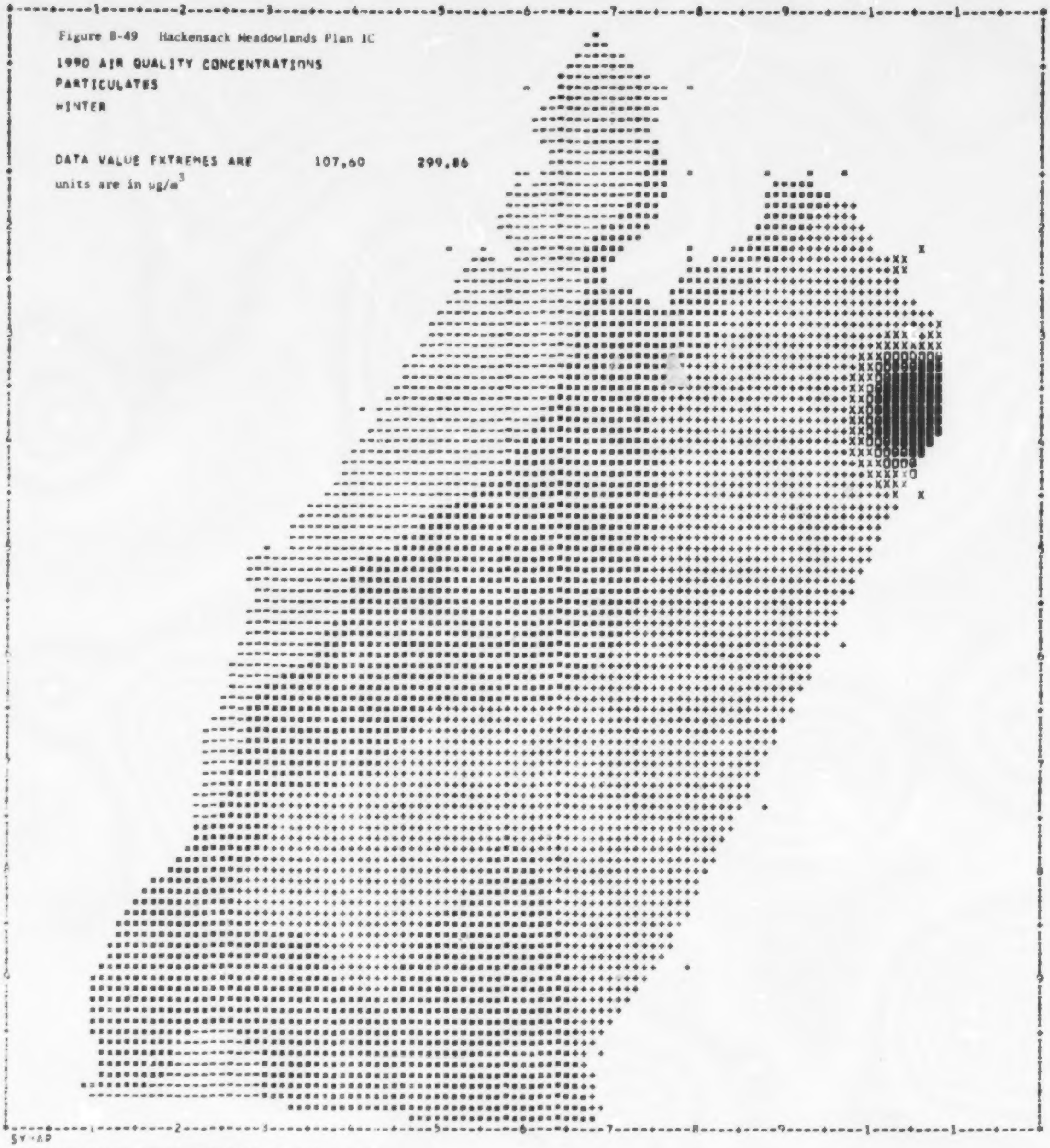


Figure 8-49 Hackensack Meadowlands Plan 1C

1990 AIR QUALITY CONCENTRATIONS

PARTICULATES

WINTER

DATA VALUE EXTREMES ARE 107.60 299.86

units are in $\mu g/m^3$

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM    70.00     87.50    105.00    122.50    140.00    157.50    175.00    192.50    ABOVE
 MAXIMUM    87.50  -  105.00   122.50    140.00    157.50    175.00    192.50    210.00    210.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

            12.50     12.50     12.50     12.50     12.50     12.50     12.50     12.50

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL       1         2         3         4         5         6         7         8         H
         *******************************************************************************************
          .........  ########  --------  ********  +++++++++  XXXXXXXX  OOOOOOOO  @@@@@@@@  ||||||||
          .........  ########  --------  ********  +++++++++  XXXXXXXX  OOOOOOOO  @@@@@@@@  ||||||||
 SYMBOLS  .........  ########  --------  ********  +++++++++  XXXXXXXX  OOOOOOOO  @@@@@@@@  ||||||||
          .........  ########  --------  ********  +++++++++  XXXXXXXX  OOOOOOOO  @@@@@@@@  ||||||||
          .........  ########  --------  ********  +++++++++  XXXXXXXX  OOOOOOOO  @@@@@@@@  ||||||||
         *******************************************************************************************
 FREQ.        0         0        22        37        38         2         0         0         1
```

Figure B-50 Hackensack Meadowlands Plan I

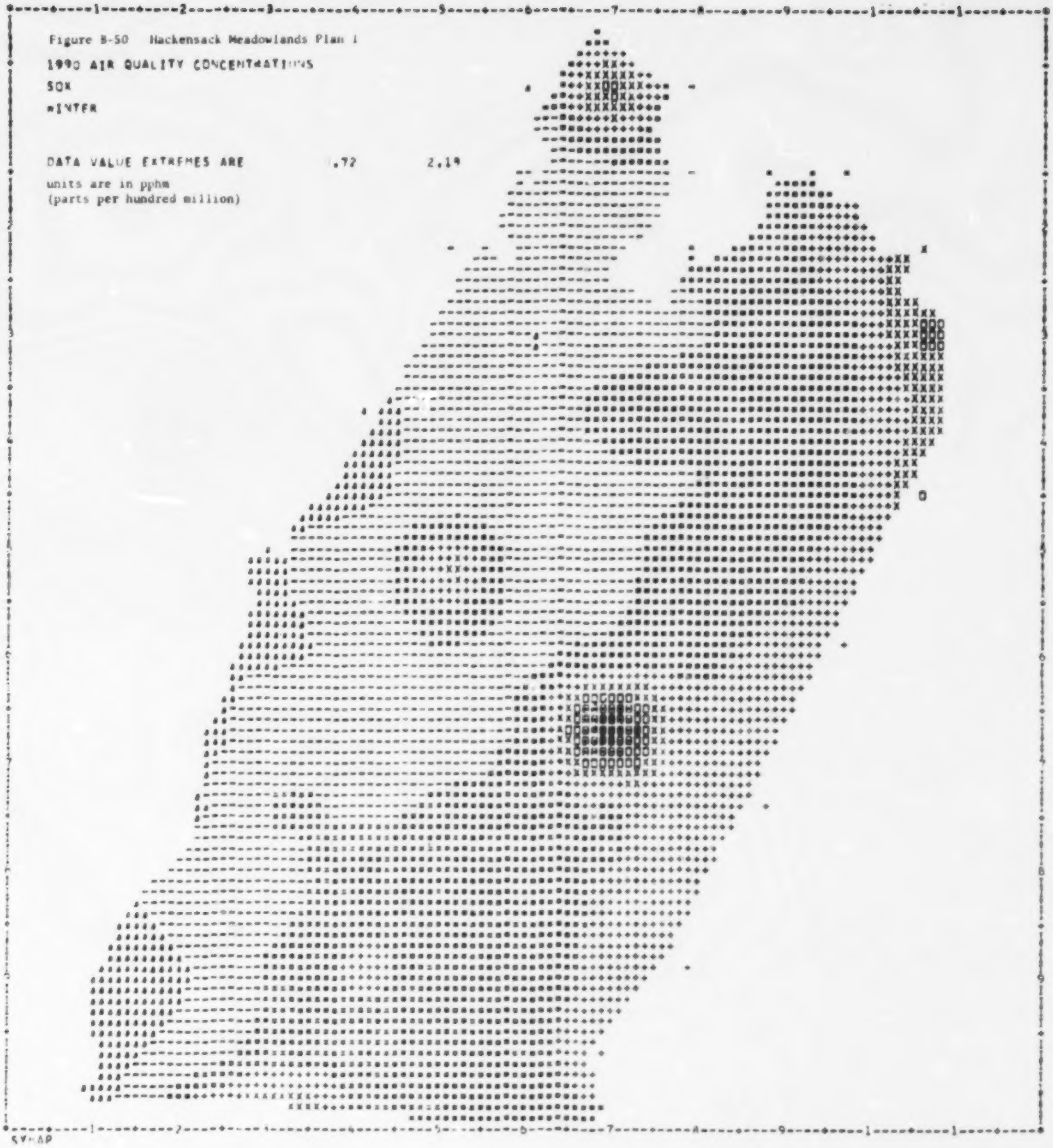
1990 AIR QUALITY CONCENTRATIONS

SOX

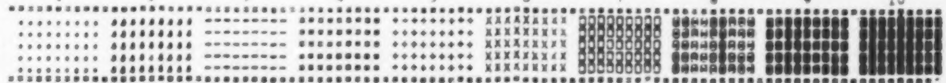
WINTER

DATA VALUE EXTREMES ARE .72 2.19

units are in pphm
(parts per hundred million)



```
SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM      .40      0.60      0.80      1.00      1.20      1.40      1.60      1.80      2.00      2.20
 MAXIMUM      .60      0.80      1.00      1.20      1.40      1.60      1.80      2.00      2.20      2.40

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL          1         2         3         4         5         6         7         8         9        10
```



```
 FREQ.    [illegible]     9        32        36        14         4         4         0         1         0
```

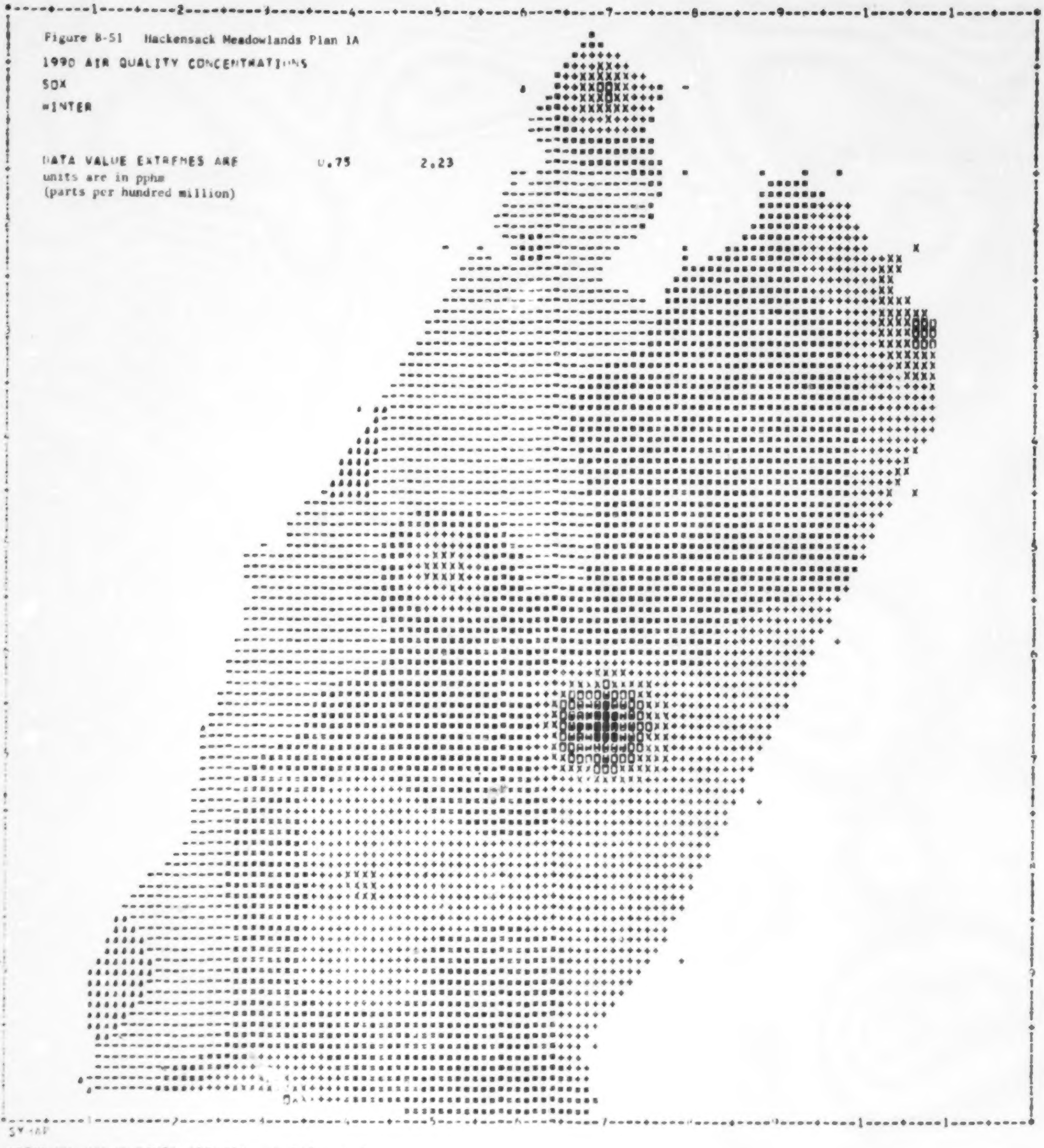


Figure 8-51 Hackensack Meadowlands Plan 1A

1990 AIR QUALITY CONCENTRATIONS

SOX

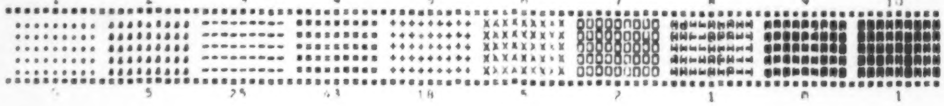
WINTER

DATA VALUE EXTREMES ARE 0.75 2.23

units are in pphm

(parts per hundred million)

```
SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM       0.40     0.60     0.80     1.00     1.20     1.40     1.60     1.80     2.00     2.20
 MAXIMUM       0.60     0.80     1.00     1.20     1.40     1.60     1.80     2.00     2.20     2.40

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL         1        2        3        4        5        6        7        8        9        10
```



```
  SYMBOLS

  FREQ.         0        5        25       43       18       5        2        1        0        1
```

Figure B-52 Hackensack Meadowlands Plan 1B

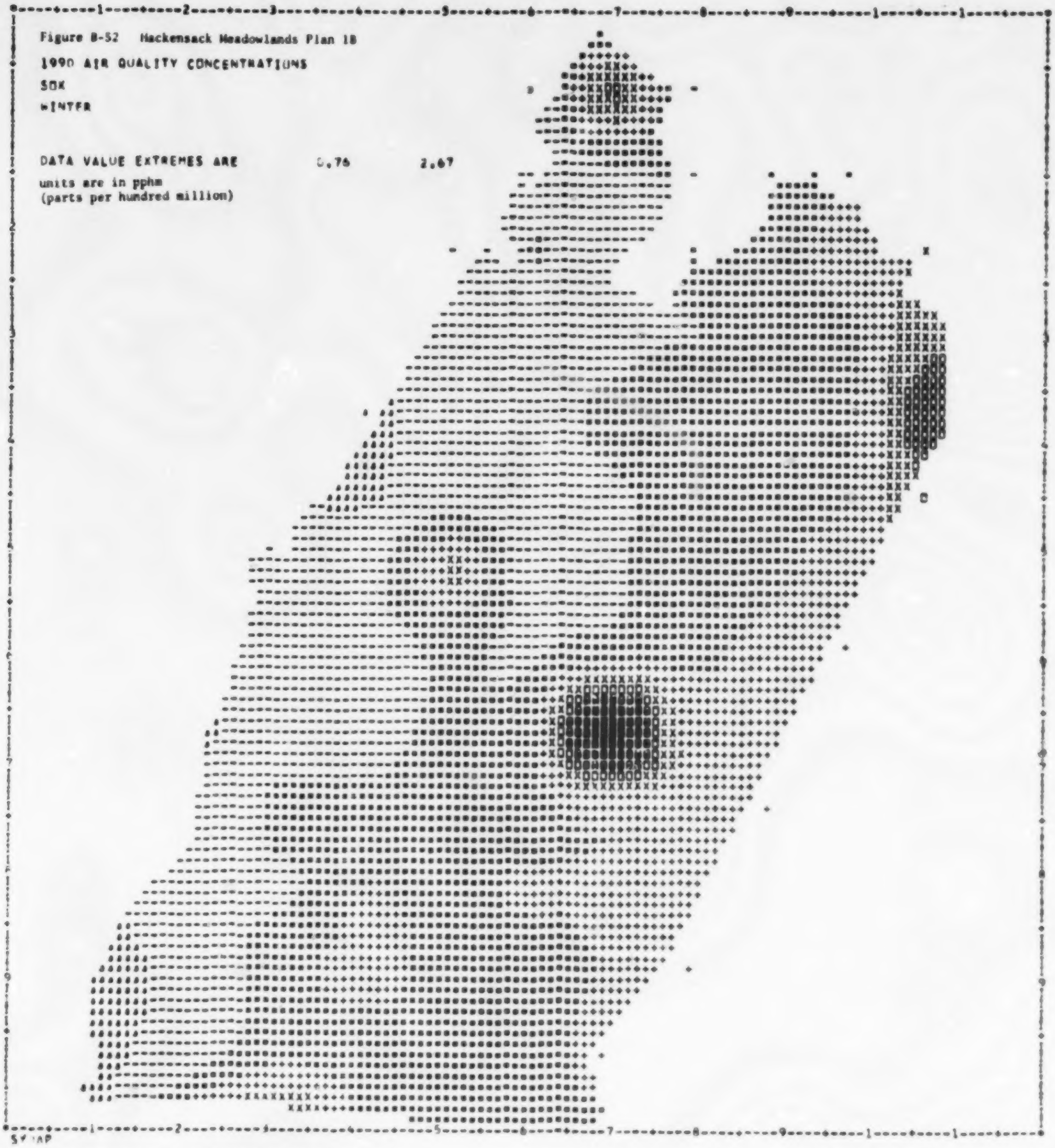
1990 AIR QUALITY CONCENTRATIONS

SOX

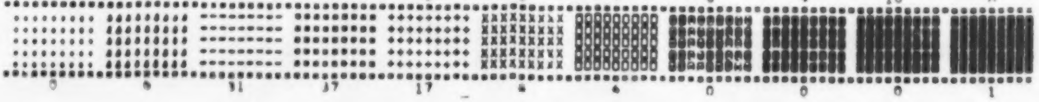
WINTER

DATA VALUE EXTREMES ARE 0.76 2.67

units are in pphm
(parts per hundred million)



```
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

                                                                                                    ABOVE
 MINIMUM     0.40      0.60      0.80      1.00      1.20      1.40      1.60      1.80      2.00      2.20      2.40
 MAXIMUM     0.60      0.80      1.00      1.20      1.40      1.60      1.80      2.00      2.20      2.40

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL         1         2         3         4         5         6         7         8         9        10         H
```



```
 FREQ.         0         6        31        37        17         4         6         0         0         0         1
```

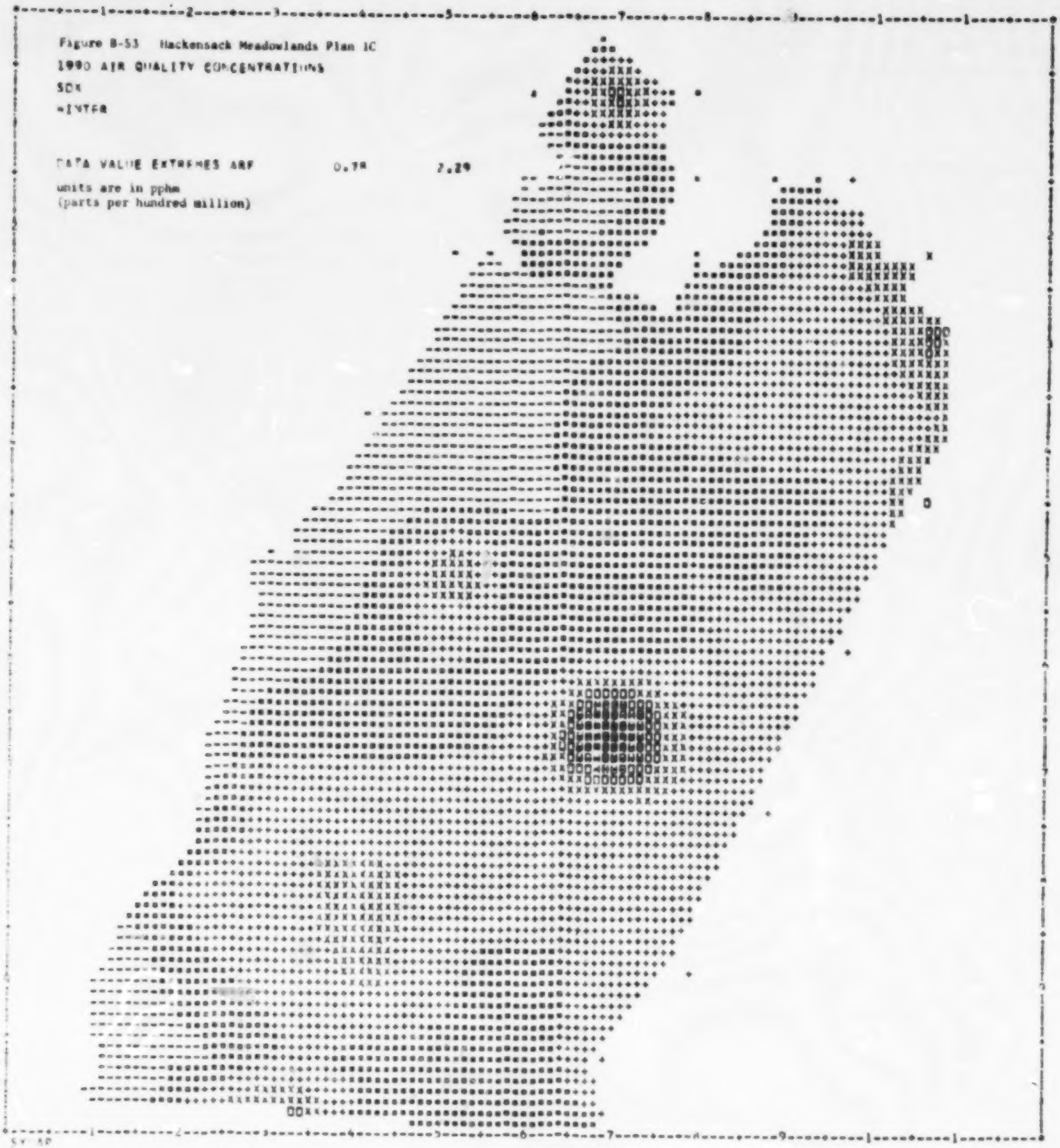


Figure B-53 Hackensack Meadowlands Plan 1C

1990 AIR QUALITY CONCENTRATIONS

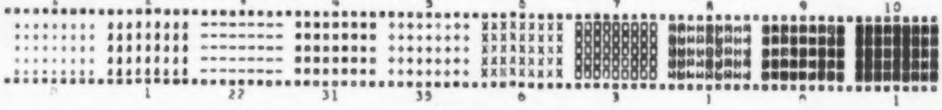
SOX

WINTER

DATA VALUE EXTREMES ARE 0.78 2.29

units are in pphm
(parts per hundred million)

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM      .40     0.60     0.80     1.00     1.20     1.40     1.60     1.80     2.00     2.20
 MAXIMUM      .60     0.80     1.00     1.20     1.40     1.60     1.80     2.00     2.20     2.40

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

            10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL        1        2        3        4        5        6        7        8        9        10
```



```
 SYMBOLS
 FREQ.        0        1        22       31       35       6        3        1        0        1
```

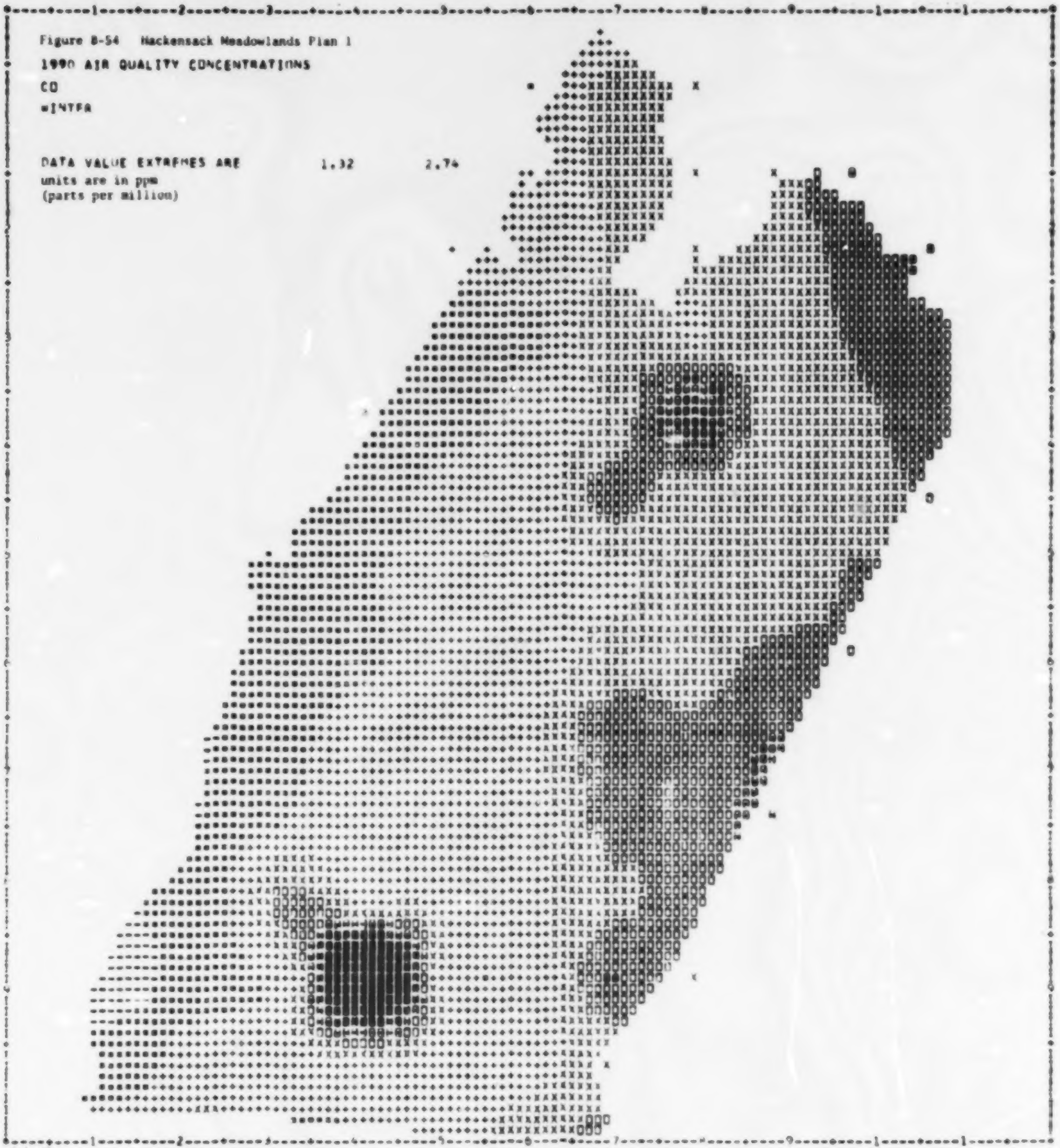


Figure 8-54 Hackensack Meadowlands Plan 1
1990 AIR QUALITY CONCENTRATIONS
CO
WINTER
DATA VALUE EXTREMES ARE 1.32 2.74
units are in ppm
(parts per million)

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)
                                                                                           ABOVE
 MINIMUM    1.05     1.15     1.25     1.35     1.45     1.55     1.65     1.75     1.85     1.95     2.05
 MAXIMUM    1.15     1.25     1.35     1.45     1.55     1.65     1.75     1.85     1.95     2.05

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

           10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL       1        2        3        4        5        6        7        8        9        10       H

 SYMBOLS   .......  '''''''  -------  =======  +++++++  XXXXXXX  OOOOOOO  ØØØØØØØ  ███████  ███████  ███████

 FREQ.       0        0        2        17       33       29       16       5        1        0        1
```

Figure D-55 Hackensack Meadowlands Plan 1A

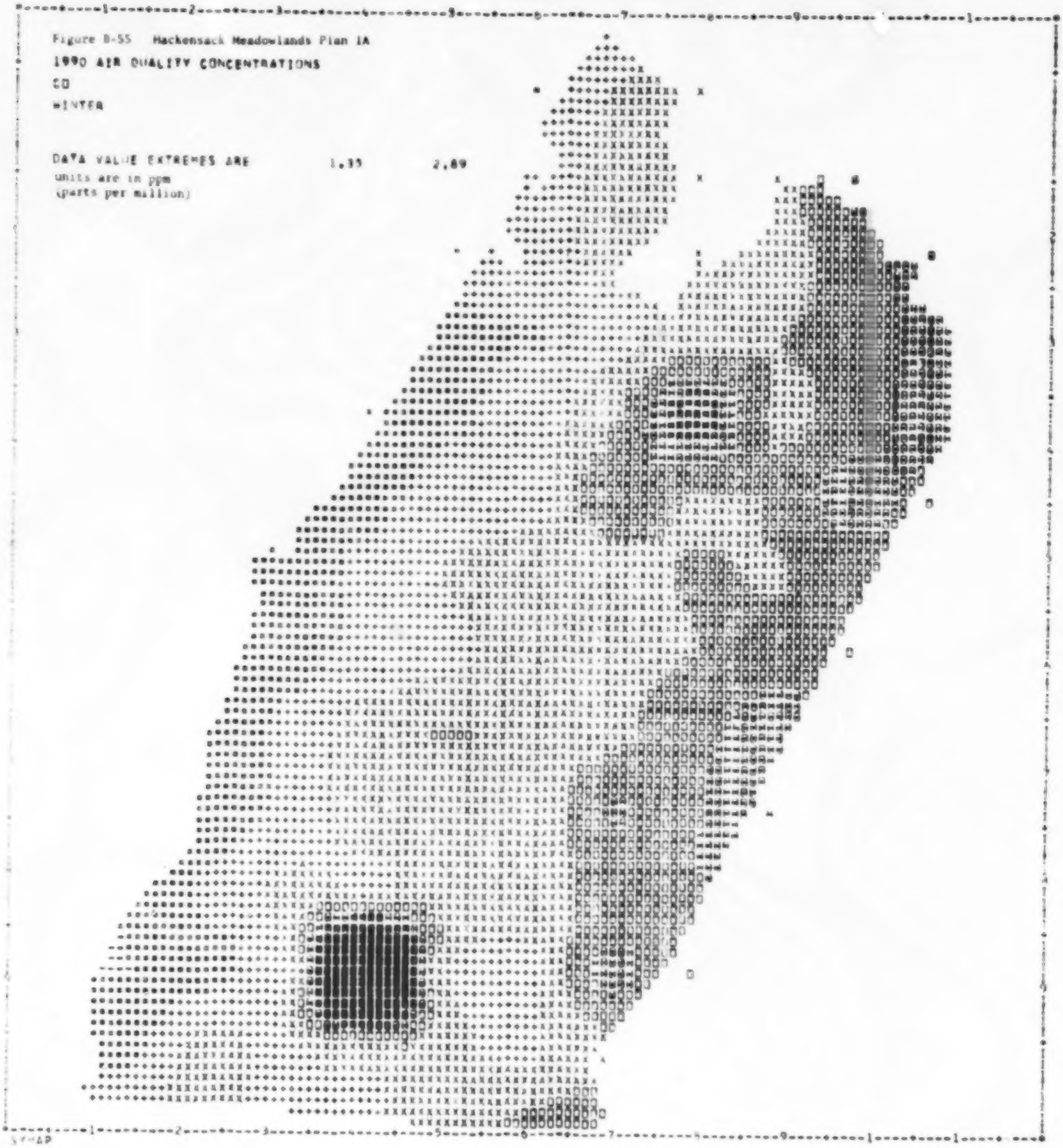
1990 AIR QUALITY CONCENTRATIONS

CO

WINTER

DATA VALUE EXTREMES ARE 1.35 2.89

units are in ppm
(parts per million)



ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
(MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	1.05	1.15	1.25	1.35	1.45	1.55	1.65	1.75	1.85	1.95	ABOVE
MAXIMUM	1.15	1.24	1.34	1.44	1.55	1.64	1.75	1.85	1.95	2.04	2.04

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10	H
SYMBOLS	·	'	-	=	+	X	O	▨	▩	█	█
FREQ.	0	0	1	12	23	35	17	13	0	1	1

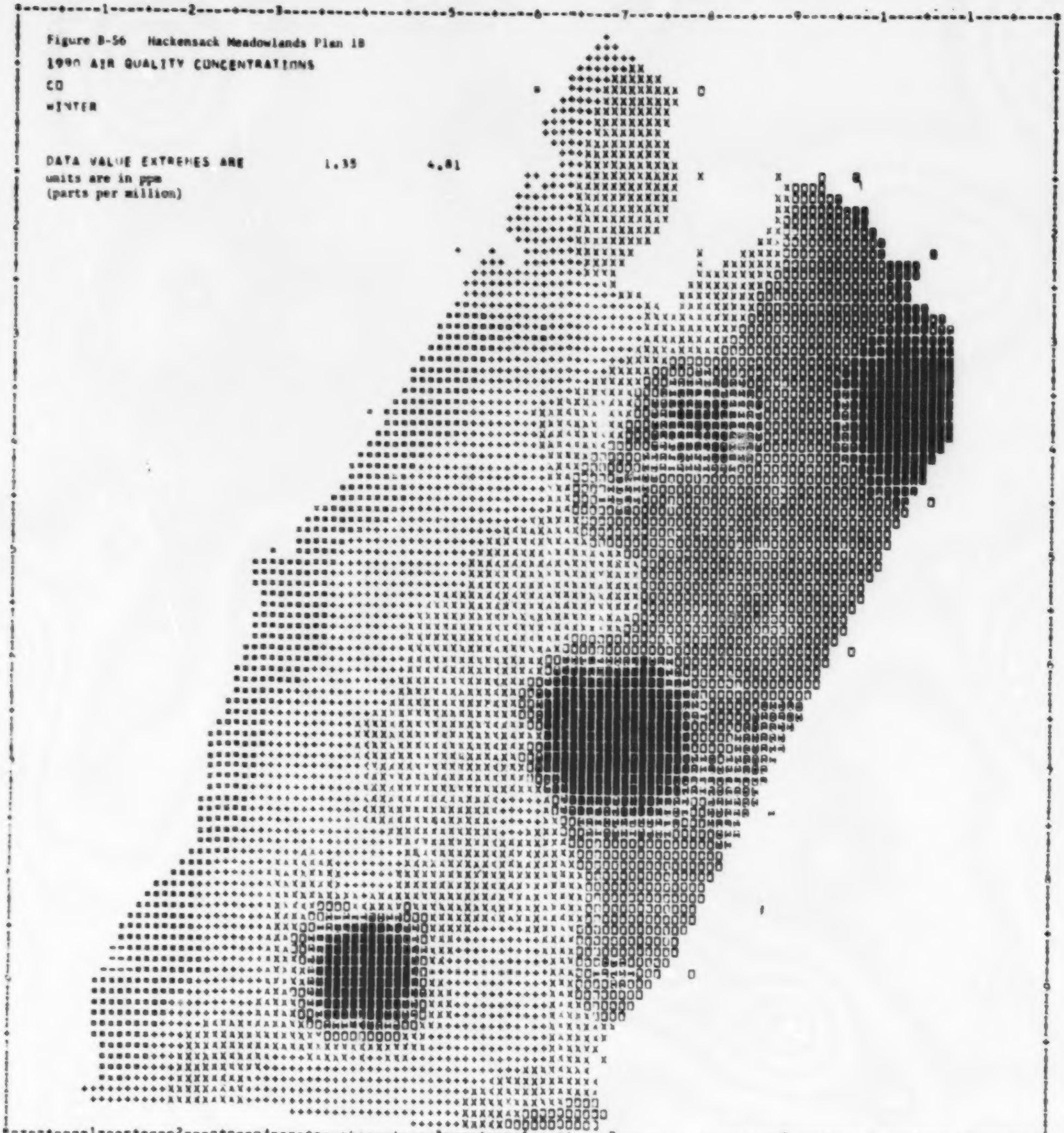


Figure B-56 Hackensack Meadowlands Plan 1B

1990 AIR QUALITY CONCENTRATIONS

CO

WINTER

DATA VALUE EXTREMES ARE 1.35 4.81

units are in ppm

(parts per million)

SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
(*MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM	1.05	1.15	1.25	1.35	1.45	[illegible]	1.65	1.75	1.85	1.95	ABOVE 2.05
MAXIMUM	1.15	1.25	1.35	1.45	1.55	[illegible]	1.75	1.85	1.95	2.05	

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

10.00	10.00	10.00	10.00	10.00	[illegible]	10.00	10.00	10.00	10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL

LEVEL	1	2	3	4	5	6	7	8	9	10	H
SYMBOLS	·	▪	–	■	◆	X	O	Ø	●	▮	█
FREQ.	0	0	1	13	23	[illegible]	[illegible]	9	0	1	3

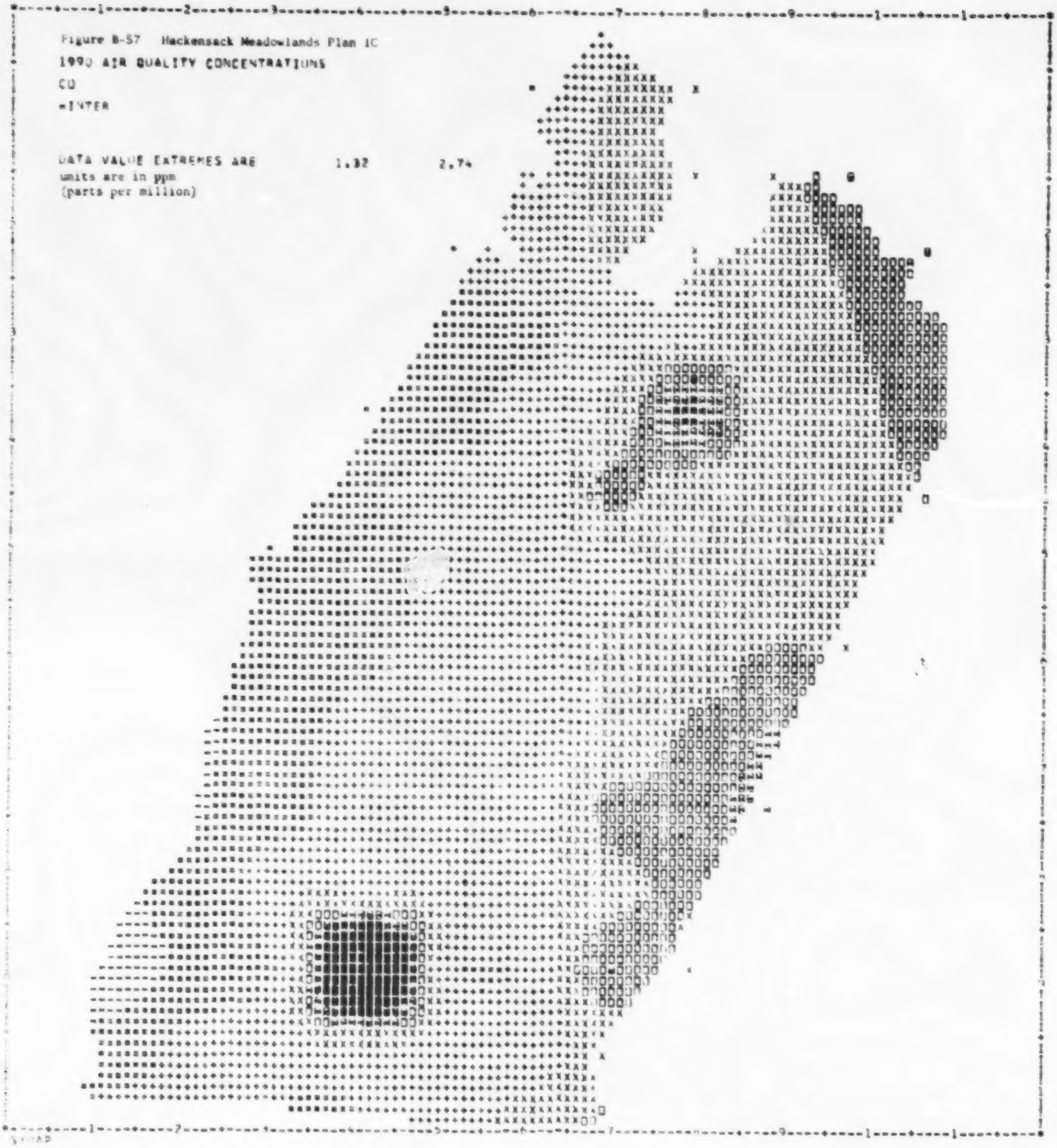


Figure B-57 Hackensack Meadowlands Plan 1C

1990 AIR QUALITY CONCENTRATIONS

CO

WINTER

DATA VALUE EXTREMES ARE 1.32 2.74

units are in ppm
(parts per million)

```
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
        (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM     1.05     1.15     1.25     1.35     1.45     1.55     1.65     1.75     1.85     1.95     ABOVE
 MAXIMUM     1.15  .  1.24     1.35     1.45     1.55     1.65     1.75     1.85     1.95     2.05     2.05

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL        1        2        3        4        5        6        7        8        9        10       H
```

```
 SYMBOLS

 FREQ.        0        0        3        19       33    [illegible]  12       4        1        0        1
```

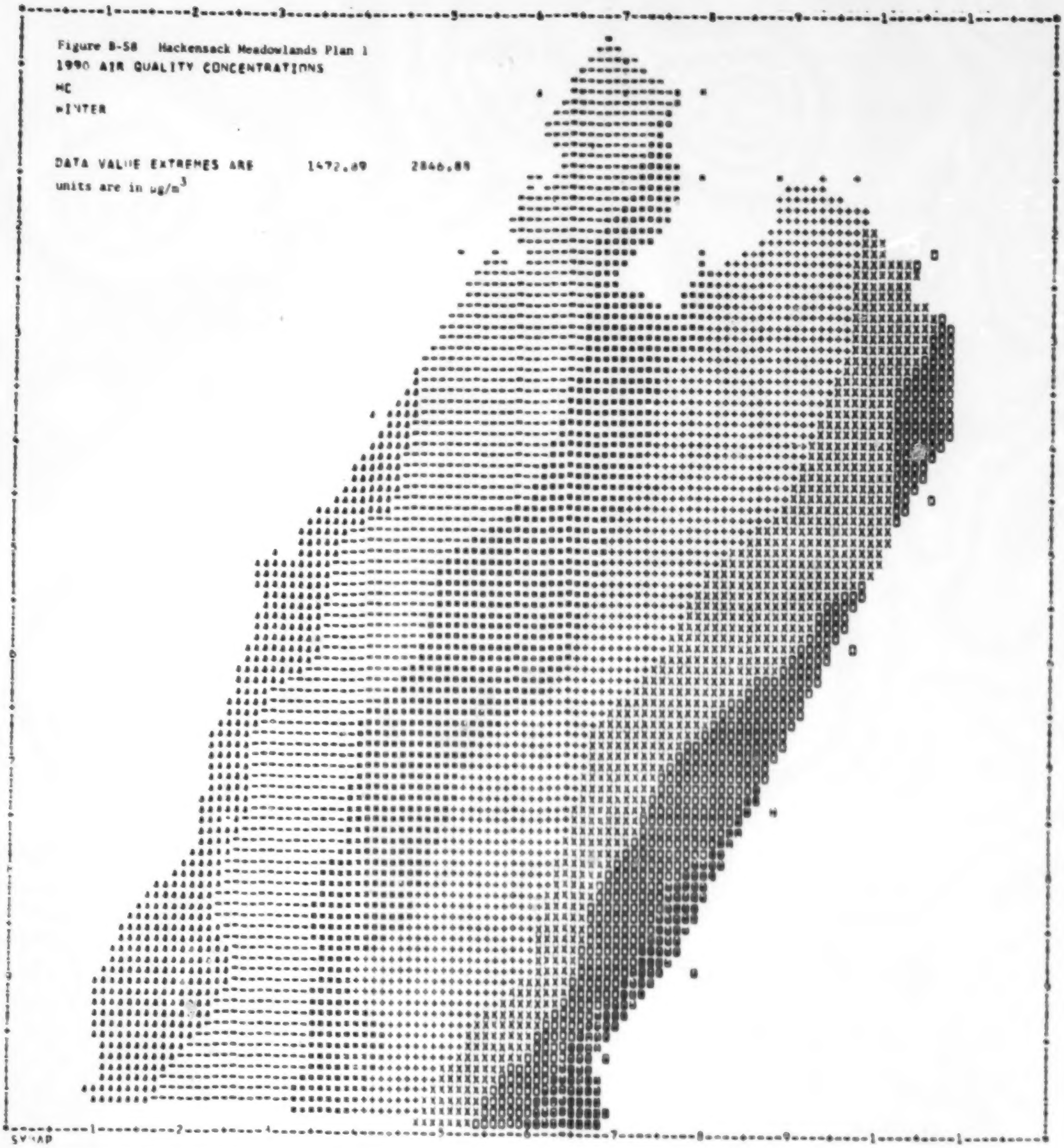


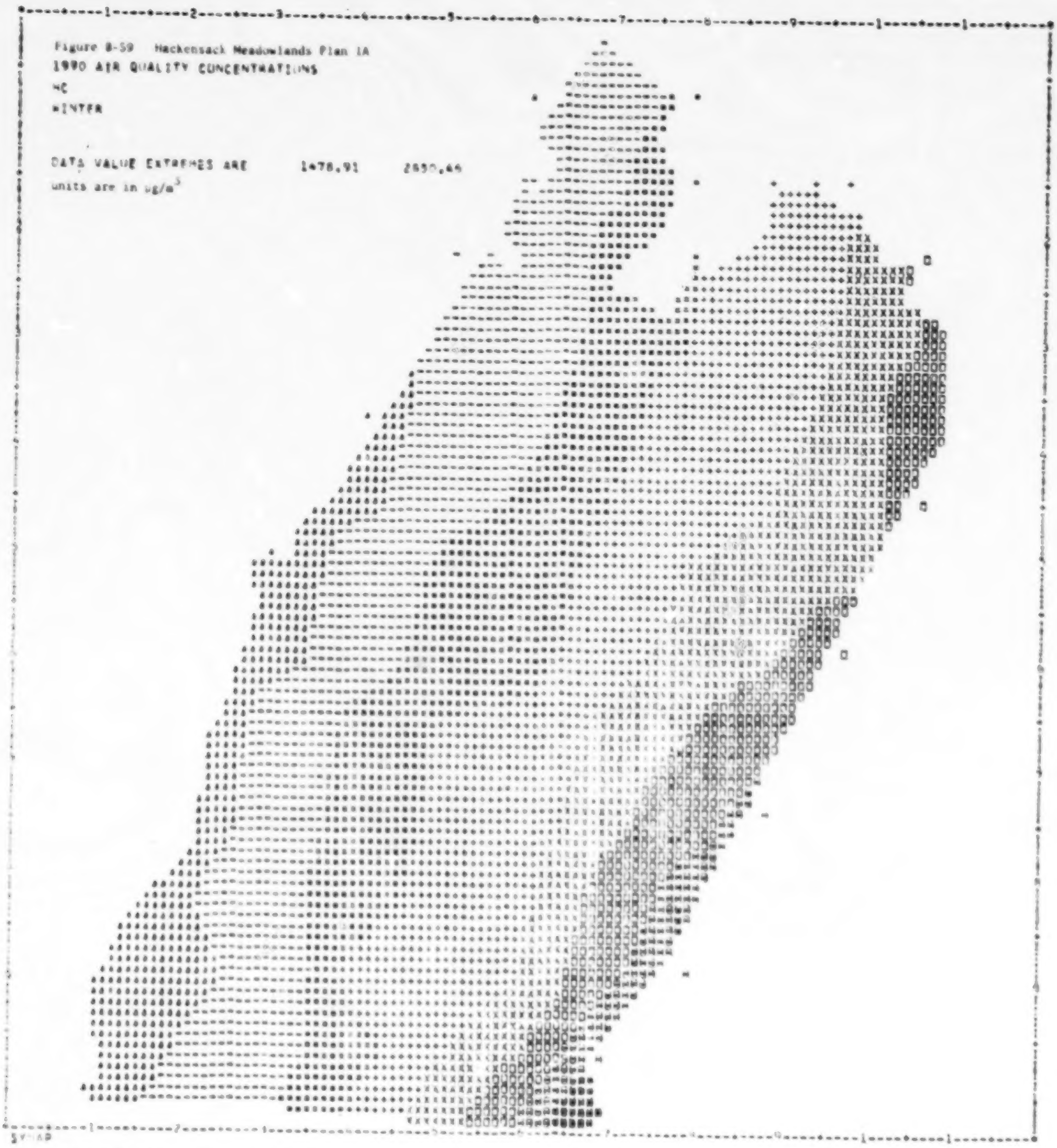
Figure B-58 Hackensack Meadowlands Plan 1
1990 AIR QUALITY CONCENTRATIONS
HC
WINTER

DATA VALUE EXTREMES ARE 1472.09 2846.89
units are in μg/m^3

```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM   1248.00   1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00     ABOVE
 MAXIMUM   1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00   2808.00   2808.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL         1         2         3         4         5         6         7         8         9        10         H

 SYMBOLS                                                    XXXXXXXX  OOOOOOOO

 FREQ.         0        12        20        20        21        11        10         5         0         0         1
```

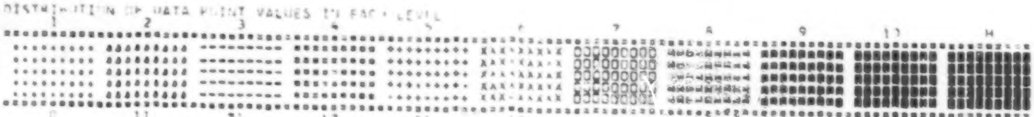
Figure 8-59 Hackensack Meadowlands Plan 1A
1990 AIR QUALITY CONCENTRATIONS
HC
WINTER

DATA VALUE EXTREMES ARE 1478.91 2850.46
units are in ug/m^3



```
SYMAP
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM   1248.00   1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00    ABOVE
 MAXIMUM   1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00   2808.00   2808.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

           10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL       1         2         3         4         5         6         7         8         9        10         H
```

SYMBOLS



```
 FREQ.       0        11        21        17        21        13        11         5         0         0         1
```

Figure B-60 Hackensack Meadowlands Plan 1B

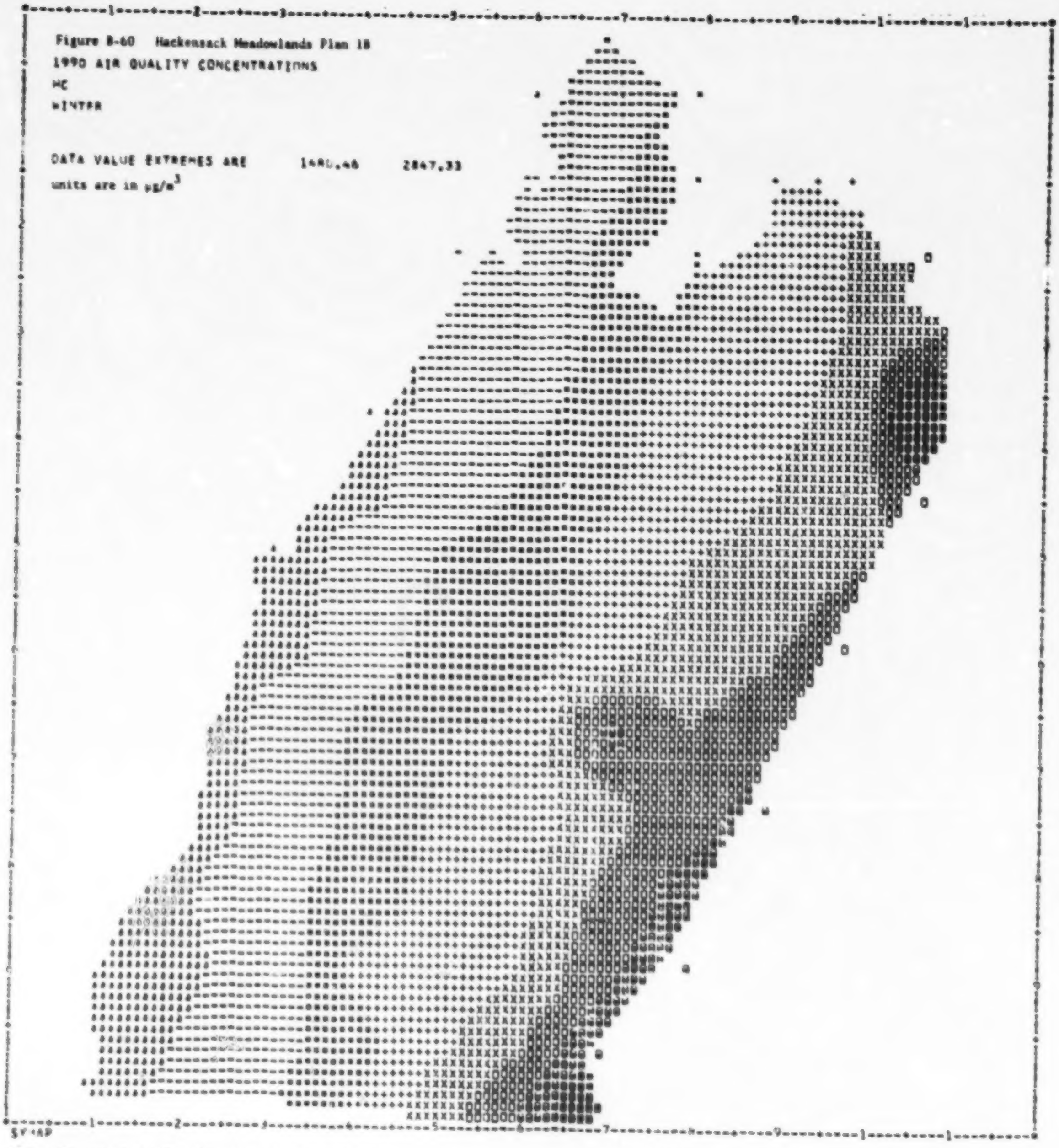
1990 AIR QUALITY CONCENTRATIONS

HC

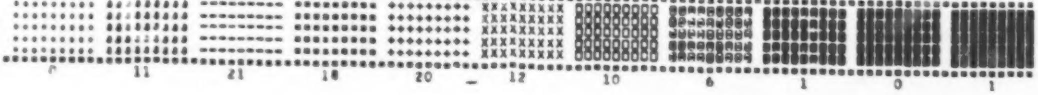
WINTER

DATA VALUE EXTREMES ARE 1480.46 2847.33

units are in µg/m³



```
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
    ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM   1248.00  1404.00  1560.00  1716.00  1872.00  2028.00  2184.00  2340.00  2496.00  2652.00    ABOVE
MAXIMUM   1404.00  1560.00  1716.00  1872.00  2028.00  2184.00  2340.00  2496.00  2652.00  2808.00  2808.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

            10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL       1        2        3        4        5        6        7        8        9       10        H
```

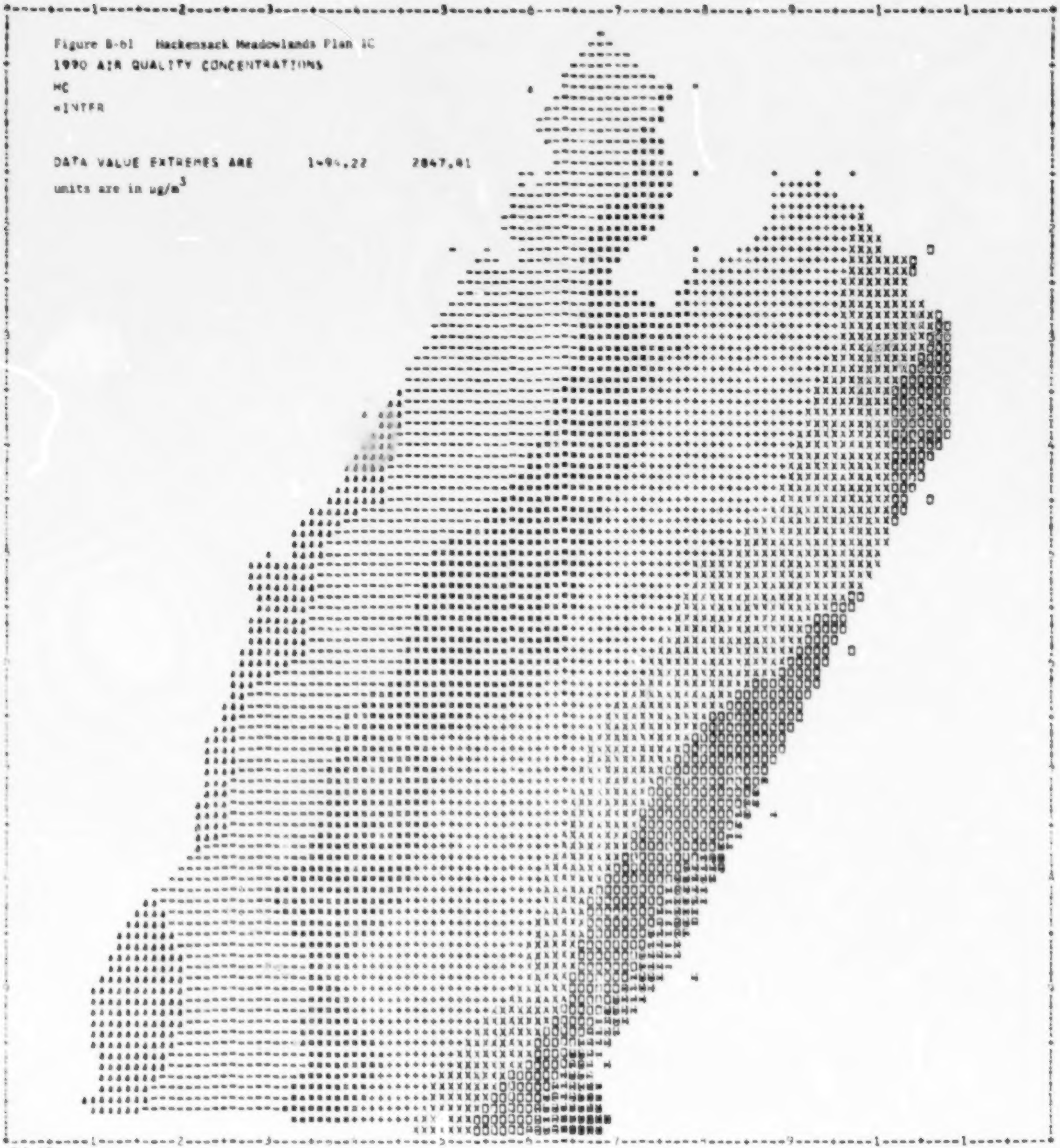


```
  FREQ.       0       11       21       18       20       12       10        6        1        0        1
```

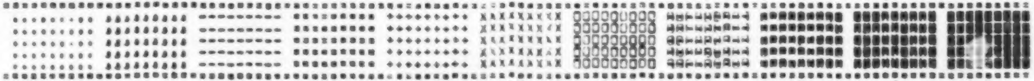
Figure B-61 Hackensack Meadowlands Plan 1C
1990 AIR QUALITY CONCENTRATIONS
HC
WINTER

DATA VALUE EXTREMES ARE 1494.22 2847.81

units are in $\mu g/m^3$



```
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM   1248.00   1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00     ABOVE
 MAXIMUM   1404.00   1560.00   1716.00   1872.00   2028.00   2184.00   2340.00   2496.00   2652.00   2808.00   2808.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

            10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL        1         2         3         4         5         6         7         8         9        10         H
```



```
 FREQ.        0        10        21        17        22        13        11         5         0         0         1
```

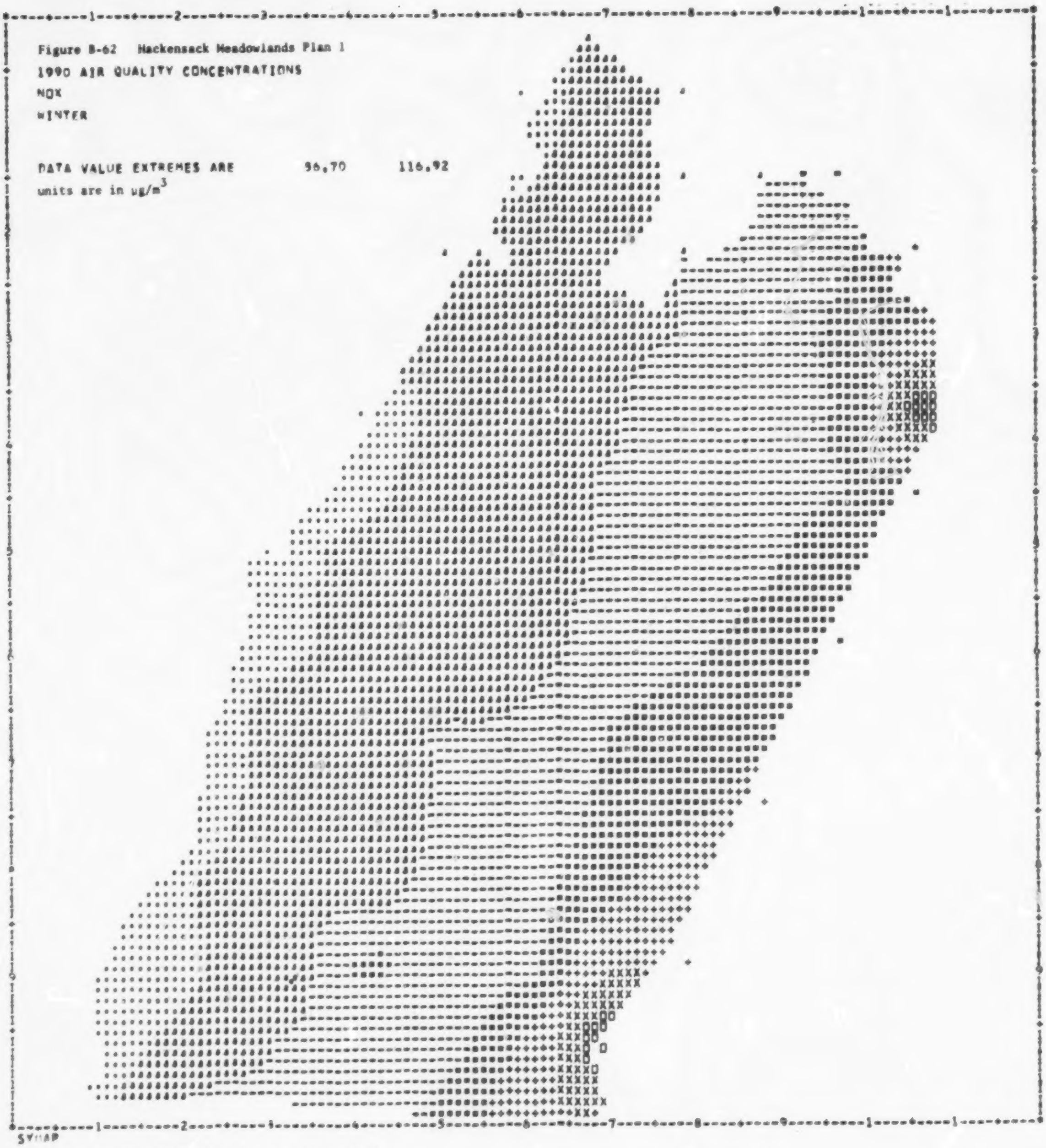


Figure B-62 Hackensack Meadowlands Plan 1
1990 AIR QUALITY CONCENTRATIONS
NOX
WINTER

DATA VALUE EXTREMES ARE 96.70 116.92
units are in $\mu g/m^3$

```
SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
     (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

MINIMUM    50.00    60.00    70.00    80.00    90.00   100.00   110.00   120.00   130.00   140.00
MAXIMUM    60.00    70.00    80.00    90.00   100.00   110.00   120.00   130.00   140.00   150.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

           10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
LEVEL        1        2        3        4        5        6        7        8        9       10
SYMBOLS  .........  #########  ---------  ■■■■■■■■■  +++++++++  XXXXXXXXX  000000000  █████████  █████████  █████████
FREQ.       11       34       31       13        9        0        2        0        0        0
```

Figure B-63   Hackensack Meadowlands Plan 1A

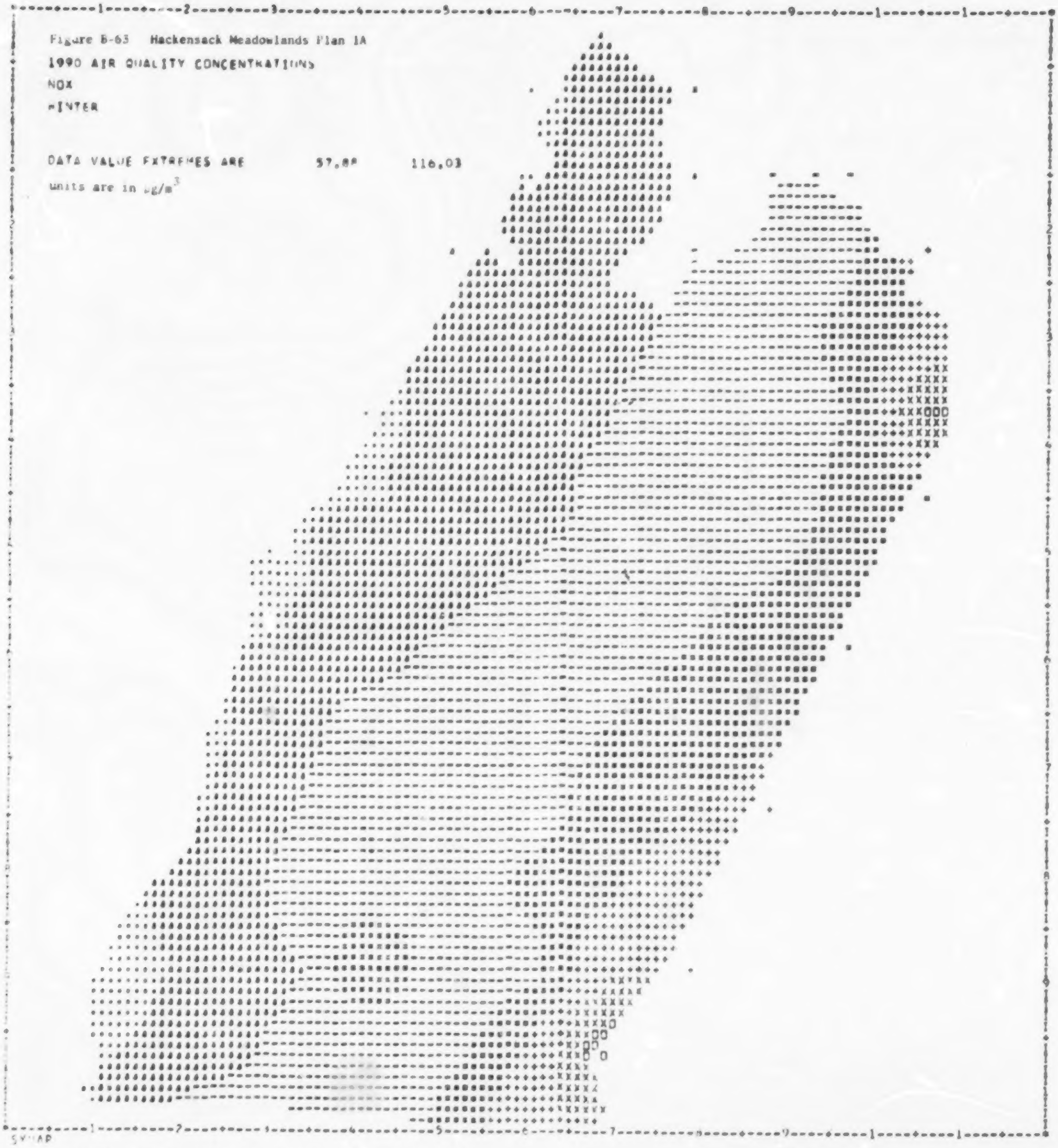
1990 AIR QUALITY CONCENTRATIONS

NOX

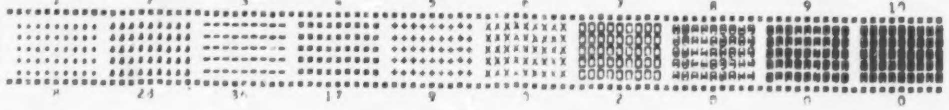
WINTER

DATA VALUE EXTREMES ARE   57.88   116.03

units are in µg/m³



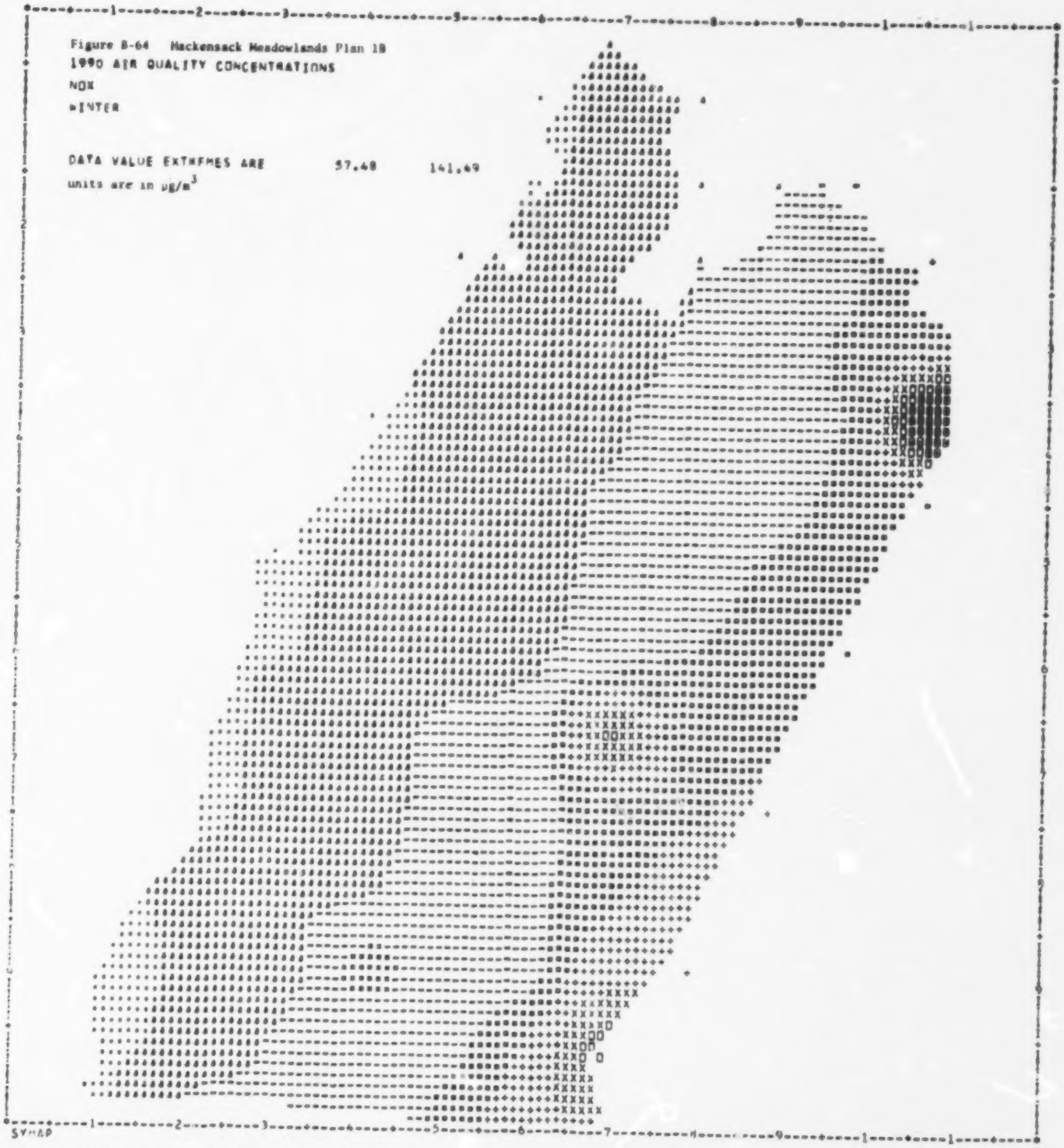
```
SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      ('MAXIMUM' INCLUDED IN HIGHEST LEVEL ONLY)

  MINIMUM     50.00     60.00     70.00     80.00     90.00    100.00    110.00    120.00    130.00    140.00
  MAXIMUM     60.00     70.00     80.00     90.00    100.00    110.00    120.00    130.00    140.00    150.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

              10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
  LEVEL         1         2         3         4         5         6         7         8         9        10
```



```
  FREQ.         8        23        36        17         9         3         2         0         0         0
```

Figure B-64 Hackensack Meadowlands Plan 1B
1990 AIR QUALITY CONCENTRATIONS
NOX
WINTER

DATA VALUE EXTREMES ARE 57.48 141.69
units are in $\mu g/m^3$



```
ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
   (MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM    50.00    60.00    70.00    80.00    90.00   100.00   110.00   120.00   130.00   140.00
 MAXIMUM    60.00    70.00    80.00    90.00   100.00   110.00   120.00   130.00   140.00   150.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

            10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00    10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL        1        2        3        4        5        6        7        8        9       10
 FREQ.       11       34       28       16        8        0        2        0        0        1
```

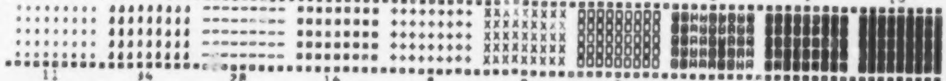


Figure 8-65 Hackensack Meadowlands Plan 1C

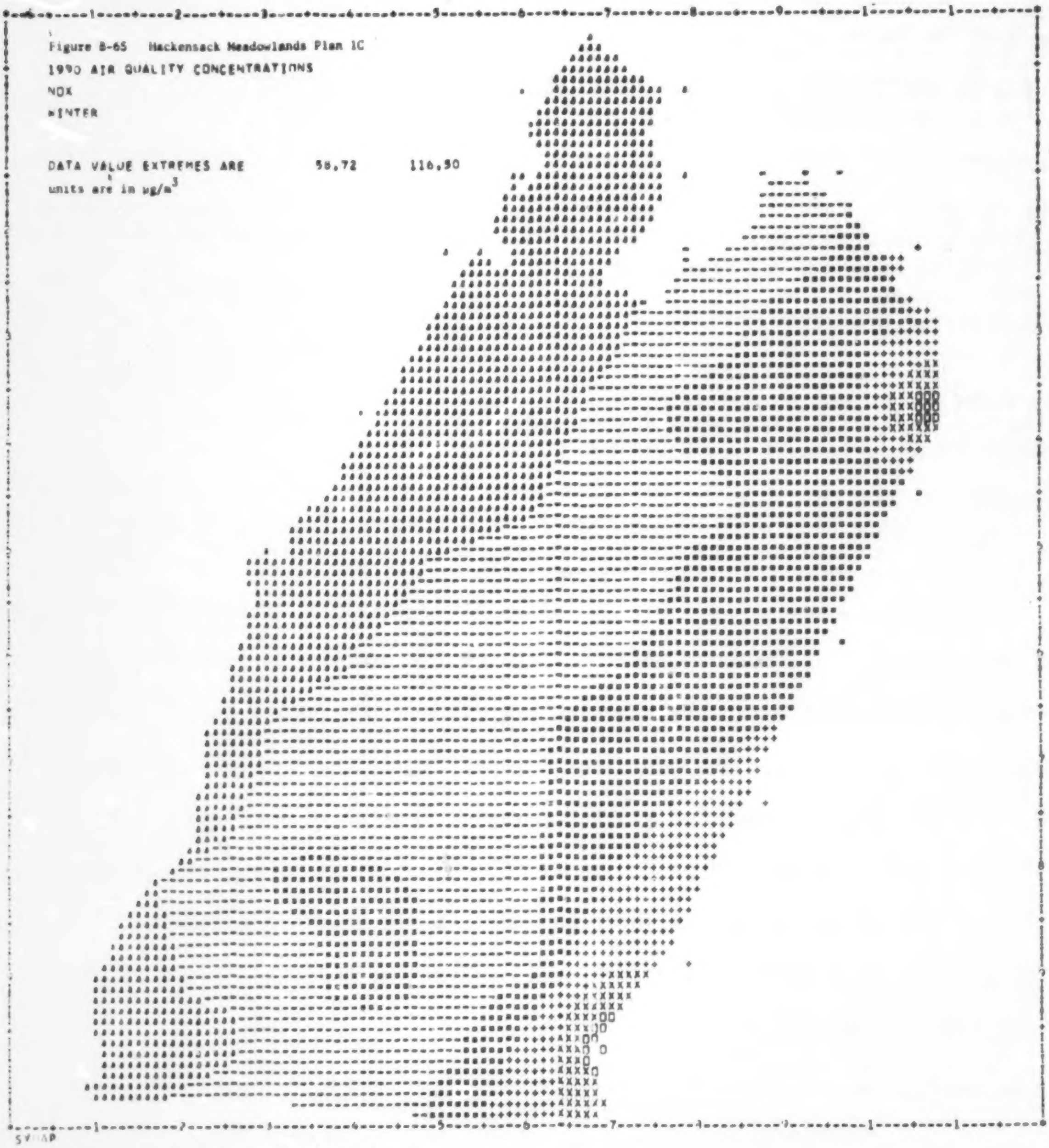
1990 AIR QUALITY CONCENTRATIONS

NOX

WINTER

DATA VALUE EXTREMES ARE 58.72 116.50

units are in $\mu g/m^3$



```
SYMAP

ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL
      (*MAXIMUM INCLUDED IN HIGHEST LEVEL ONLY)

 MINIMUM     50.00     60.00     70.00     80.00     90.00    100.00    110.00    120.00    130.00    140.00
 MAXIMUM     60.00     70.00     80.00     90.00    100.00    110.00    120.00    130.00    140.00    150.00

PERCENTAGE OF TOTAL ABSOLUTE VALUE RANGE APPLYING TO EACH LEVEL

             10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00     10.00

FREQUENCY DISTRIBUTION OF DATA POINT VALUES IN EACH LEVEL
 LEVEL         1         2         3         4         5         6         7         8         9        10

 SYMBOLS

 FREQ.         2        26        35        23        12         0         2         0         0         0
```

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-450/3-74-056-d	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE HACKENSACK MEADOWLANDS AIR POLLUTION STUDY- The Evaluation and Ranking of Land Use Plans		5. REPORT DATE November 1973
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Byron H. Willis		8. PERFORMING ORGANIZATION REPORT NO. ERT Project No. P-244-3
9. PERFORMING ORGANIZATION NAME AND ADDRESS Environmental Research and Technology, Inc. 429 Marrett Road Lexington, Massachusetts 02173		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. EHSD 71-39
12. SPONSORING AGENCY NAME AND ADDRESS Environmental Protection Agency Office of Air Quality Planning and Standards Research Triangle Park, North Carolina 27711		13. TYPE OF REPORT AND PERIOD COVERED Final
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared in cooperation with the New Jersey Department of Environmental Protection, Office of the Commissioner, Labor and Industry Building, Trenton, N. J. 08625

16. ABSTRACT

The Hackensack Meadowlands Air Pollution Study consists of a summary report and five task reports. The summary report discusses the procedures developed for considering air pollution in the planning process and the use of these procedures to evaluate four alternative land use plans for the New Jersey Hackensack Meadowlands for 1990. The task reports describe (1) the emission projection methodology and its application to the Hackensack Meadowlands; (2) the model for predicting air quality levels and its validation and calibration: (3) the evaluation and ranking of the land use plans; (4) the planning guidelines derived from the analysis of the plans; and (5) the software system.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Land Use Planning and Zonning Local Governments County Governments State Governments Regional Governments Air Pollution Control		

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